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A

PRACTICAL COURSE

OF

MILITARY SURVEYING,

INCLUDING

THE PRINCIPLES OF TOPOGRAPHICAL DRAWING.

BY

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PREFACE.

Topography is to Military Science what Music is to feminine accomplishments: it does not claim the first rank, but an accomplished officer should be familiar with it.

The subject is in itself of the greatest simplicity, the only foundation requisite for a beginner being a trifling amount of Geometry: yet very few officers, Sandhurst and Woolwich men excepted, can make a survey—nay, read a plan.

This, I believe, is to be accounted for by the want of fixed rules to figure the ground. At his first step a beginner is lost among the endless varieties of horizontal style, vertical style, pencil-brush work, &c., the mutual relations of which he is unable to understand; and furthermore, bewildered by the cobweb of the plotting book, and the screws of the theodolite, he readily gives up the attempt.

In the following pages, originally written for the Military College of Sunbury, I have endeavoured to remove the difficulty in explaining the theory of the ground, and confining myself to those practical operations only which are needed in actual service.

Major Petley, the head professor of Military Surveying at the Royal Military College, has kindly favoured me with his excellent series of plates (xi to xvii) illustrating the horizontal method, and Captain Richards, the talented instructor in Military Drawing, at the same Institution, has obliged me with a Military Sketch on the same system. (xviii.)

The vertical system I have, I trust, rendered equally intelligible by a series of plates, properly graduated.

Lastly, for the operations of the field, I have carefully avoided the intricacies of trigonometrical surveys, and exclusively employed the most simple instruments.

I thus venture the publication of this volume, feeling confident that an officer who will steadily repeat on the ground the operations therein described, will soon become competent to make a good Military Sketch.

A. F. LENDY.

SUNBURY, *June*, 1864.

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* It is next to impossible to compare the English and French maps; the English diapason gives a much darker shading, and its scale is different. In order to compare them properly, the *same* ground should be represented on the *same* scale.

A PRACTICAL COURSE

OF

MILITARY SURVEYING.

CHAPTER I.

DEFINITIONS.

(1.) *Topography* (surveying) is the art of describing a limited part of the surface of the earth, so as to give a good idea of its configuration and the resources it presents.

The purpose of *military topography* (military surveying) is to describe clearly the ground and position of all objects scattered over its surface that have any military importance. These objects are either natural, as mountains, hills, valleys, rivers, marshes, &c.; or artificial, as houses, enclosures, walls, fortifications, &c. All are of some military importance, since they can modify the action of troops.

The description of the surface of the earth was originally made in writing, by a greater or less number of notes: these were rather difficult to use. Imitative drawings came into use much later.

(2.) The ground can be represented in two manners: by models or by plans.

Models are made of plaster or wood, and, like a sculpture, present in a small compass the exact image of the elevations and depressions of the ground. They are expensive, take much time, and their size and weight render them unavailable for field purposes. Their sole advantage is to represent the ground to persons not familiar with the reading of maps. Of such use are the models of Sebastopol, Waterloo, &c., at the United Service Institution.

A *plan* or map is a figure which by means of a few conventional signs represents all the natural and artificial objects above alluded to in their relative position. Unlike relievos, a plan can be taken into the field, and is indeed an indispensable item in war.

By means of plans the general prepares all his operations, battles, sieges, marches, encampments, entrenchments, &c.; by their help the great deeds of war are put down in records which afford to history the most valuable materials, and to the art of war the most useful lessons.

(3.) Topography is an indispensable complement to all the military sciences, fortification, tactics, &c., since the application of their principles entirely depends on the nature of the ground; and as it is most important for an officer to appreciate at a glance the distances, slopes, and in general all the mutual relations of the various parts of a field of battle, he should remember that this *coup d'œil militaire* is only acquired by the practical study of Topography.

(4.) When a plan is intended to serve as a guide to prepare constructions on the ground, such as fortifications, buildings, &c., it is made with accuracy, and the survey is called regular. When, however, a less accurate description is needed, a survey more or less rapid is made according to the purpose in view; the survey is then called *irregular*, or *reconnoitring*, and the plan is named a *military sketch*.

In regular topography the execution of the plans requires precise methods, good instruments, and time; but in irregular surveys and reconnoitrings, instruments of a less accurate description are sufficient: sometimes they may be dispensed with; thus military sketches are made at sight, from memory, and even from mere indications and reports.

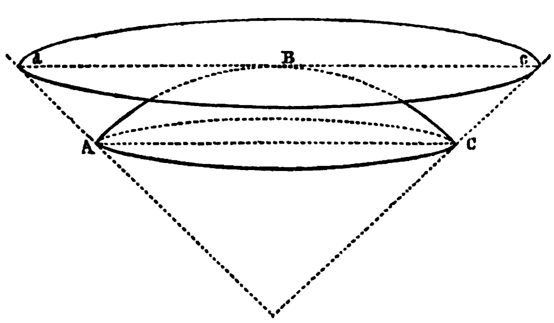
Military surveying is very seldom regular, because while time is always precious in the field, instruments are not always to be had, and, above all, because a great accuracy is not needed. The plans of fortification, those of attacks in a siege, demand, however, some precision. Regular surveying should be studied first, because it is through a thorough acquaintance with its principles and methods, together with a fair amount of practice only, that an officer will be able to make a military sketch expeditiously and without instruments.

(5.) Topography describes limited parts of the surface of the earth

only: when those parts exceed sixty miles in length, more accurate methods are resorted to, and form the province of *geodesy*. This science enables us to describe considerable tracts of land, such as kingdoms, &c.; it furnishes the materials for *geography*, and gives to topography the exact position of the important landmarks. By means of calculations and practical operations it determines with great precision the relative position of the chief points of a country, such as summits of mountains, intersections of valleys, steeples of churches, &c., leaving aside all details. Topography, on the contrary, represents all the details lying between two or three of these points, and its operations are exclusively practical.

(6.) The plan of a certain extent of ground is a figure similar to the projection of all the points of that surface on a horizontal plane; a projection being the foot of the perpendicular drawn from a point to the plane. In topography this plan is tangent to the surface of the earth, and the earth being spherical, the spherical segment A B C cannot

FIG. 1.



be represented exactly on the circle a B c. As, however, the error does not exceed three yards in sixty miles, it matters but little if we consider the earth to be plane in topography. When, however, the surface to be described is large, the sphericity cannot any longer be neglected, and geodesy takes it into account in the survey of a country.

(7.) Since topography describes both the objects lying on the surface of the earth and the undulations of that surface, it may be divided into two parts: *planimetry*, or the making the plan of those objects; and *levelling*, or representing the ground itself. Should the

ground be exactly level, topography would consist of planimetry only.

In order to represent on paper the various details of the surface of the earth, a few *conventional* signs have been adopted, and the student should, first of all, render himself thoroughly familiar with their meaning, and acquire some practice in drawing them. When he knows them so as to *read* or *copy* a plan, he has mastered one of the essential parts of topography. Before passing those signs in review we must say a word or two about the scale of the plan.

(8.) The representation of a given surface of ground can be made of different sizes according to the end in view, it being clear that the greater the accuracy required the larger the drawing must be.

The size of a dimension of the plan compared to that of the ground which it represents is called the *scale* of the plan. Thus, if a road one mile in length occupies but one inch in the drawing, the scale is that of *an inch* to *the mile*. If a wall 600 yards long is represented by a line one inch long, the scale is that of an inch to 600 yards.

Sometimes this expression is reversed, and we say, the scale of 12 chains to the inch, of 4 miles to the inch, &c.; it signifies that an inch of the plan represents 12 chains, 4 miles, &c., on the ground.

It may also happen that the scale be indicated by a representative fraction, such as $\frac{1}{2000}$ or $\frac{1}{40000}$, &c.; it implies that the dimensions of the plan are 2000, 40,000, &c., times smaller than the corresponding ones on the field.

We may readily pass from one form to the other; for instance, the scale of one inch to the mile may be called that of $\frac{1}{63360}$, since a mile contains 63,360 inches; the scale of 12 chains to the inch, or that of $\frac{1}{9504}$, signifies the same thing, because 12 chains contain 9504 inches. Conversedly, a French plan on the scale of $\frac{1}{40000}$ is a plan on the scale of 1 inch to 40,000 inches.

(9.) The selection of the scale at which a plan is to be made is not altogether arbitrary, for it depends, on the one hand, upon the degree of accuracy required in the representation of the country, and on the other upon the dimensions of the paper at disposal.

If we have to survey a distance of three miles, it is evident, that if our sheet of paper is only 24 inches long, we cannot employ a scale

larger than 24 inches to 3 miles, or 8 inches to the mile; because, with a greater scale there would not be sufficient room to represent the whole of the ground. Any smaller scale, such as 4 or 2 inches to the mile, could be employed.

Still, in employing a scale much smaller than that of 8 inches to the mile, we might meet with another inconvenience, since small objects could not be represented. The accuracy required must then guide us. At the scale of 1 inch to the mile, for instance, a field 10 yards in length would be represented only by $\frac{1}{176}$ of an inch, a dimension much too small to be easily appreciated or represented. This scale is, therefore, too small if we are expected to give every detail within 10 yards. What scale, in this case, should be adopted? In answer to this, let it be observed, that in supposing a plan to be mathematically true, we unavoidably commit in reading it an error due to the imperfection of our senses. We cannot appreciate a division smaller than the $\frac{1}{100}$ part of an inch, for our eyes cannot perceive if the points of the compasses are within $\frac{1}{100}$ of an inch too near or too far apart. This uncertainty of reading becomes $\frac{1760}{100}$, or 17 yards, at the scale of an inch to the mile. Therefore, if the plan ought to permit us to read every dimension within 10 yards, the scale should be such, that $\frac{1}{100}$ of an inch represents to the utmost 10 yards, or 1 inch represents 1000 yards. To read within 35 yards, the scale should not be under $\frac{1}{100}$ to 35 yards, or 1 inch to 3500 yards.

When a plan is given, its scale at once shows with what degree of exactitude it can be read; thus, a plan at the scale of 4 miles to the inch gives us a distance on the ground within $\frac{4}{100}$ miles, or 70 yards.

We have taken for granted that the $\frac{1}{100}$ part of an inch is the smallest dimension which we can appreciate, and, consequently, draw, although divisions of $\frac{1}{500}$ of an inch can be obtained. In topography, however, this accuracy becomes an illusion, for the paper on which plans are made contracts and expands so much under the influence of heat and moisture that the valuation of small dimensions depends upon the state of the atmosphere: $\frac{1}{100}$ being already very small.

(10.) In military surveys a great accuracy in the details is not expected, as it is not required to give *very* exact dimensions of

encampments, roads, &c. It is customary to employ the following scales:—

24 inches to the mile for plans of a fortress of field works.
12 inches for the plan of attacks on a fortress, of defensive positions, camps, &c.
6 inches for the topography of a district, the march of *armies*, sketches of roads, encampments, &c.
4 inches for larger surfaces, in reconnoitrings, &c.
1 inch is adopted for the engraved sheets of the ordnance survey.

In France the ordnance map is engraved at the scale of $\frac{1}{80000}$.

When smaller scales are employed, the plans are called maps, or geographical maps.

Every plan or map should bear the name of the scale at which it has been made.

CHAPTER II.

TOPOGRAPHICAL DRAWING.

§ I.

Conventional Signs of Planimetry.

(11.) A military plan should represent faithfully all the objects that possess some military importance or interest; such as—

Communications:—railroads, high roads, cross roads, bridle paths, foot-paths; rivers and canals, with their accessories, such as dams, towing-paths, &c. *Buildings*, including houses, farms, castles, churches, &c.; they have a double importance as habitations and defensive positions. *Enclosures:*—walls, ditches, hedges, palisades, palings, &c., which constitute a cover and an obstacle for troops. *Divisions of Culture:*—ploughed lands, gardens, orchards, vineyards, and meadows, which produce food for men and cattle; woods, which furnish fuel and material to construct defensive obstacles with, and whose border itself is a capital line of defence; fallows, or uncultivated land. Besides these, all objects should be put down which, by their peculiar position, might serve to guide or rally troops, such as crosses, fountains, &c.

(12.) The first condition which a military plan should fulfil is *accuracy*, the second, *clearness*, the third, *simplicity*. Since it is intended to serve for the combinations of the general, and for the movements of troops, it is very important that it should be as faithful as possible; and in order that all officers, even those who have no artistical turn, should easily draw and represent the various objects, and otherwise thoroughly understand a plan ready made, the conventional signs adopted to represent the objects alluded to should be clear and simple.

(13.) Plates I., II., III., and IV. contain the signs generally employed. They are partly given by Williams's Practical Geodesy, as the signs employed by the commissioners of tithes. Beginners should draw them frequently until they know them by heart; first in pencil, next in ink. On scales of 4 or more inches to the mile, every object is represented according to its real size, except trees, which are generally made larger; but on small scales the roads and canals are made wider than they really are, because they would otherwise be scarcely visible.

(14.) The plan actually executed on the ground, or "minute" as it is called, is done in pencil, and it is necessary to draw it carefully in case time should fail to ink it. This habit of making the pencil lines pure and strong will enable a beginner to survey more rapidly, and more accurately, inasmuch as he will not have to do twice the same operation, which often happens when, the minute being carelessly executed, some details are rubbed out. As soon as we return home we ink that minute with Indian ink, and, if possible, colour it. Should there be no time to ink a drawing, the pencil may be fixed by stretching the paper on a board, and washing it with a mixture of water and milk.

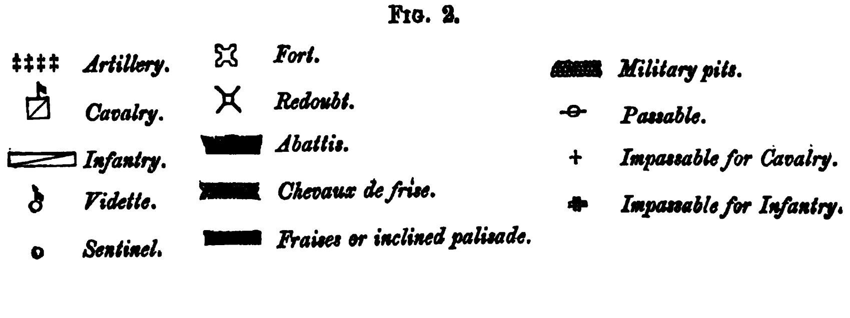
(15.) Although the light is supposed to be vertical (22), it is usual to make an exception for rocks, buildings (when the scale is less than 4 inches to the mile), water, woods, trees, and rivers when wide enough to be figured by two lines. For these objects we suppose the light coming at an angle of 45° from the left-hand corner of the plan. The thick lines render the plan more intelligible, by singling out, as it were, these objects, which are very important in a military point of view.

(16.) With regard to colours, they are employed as follows:—

Crops, yellow; *Gravel*, dots of burnt sienna over a wash of yellow ochre; *Heath*, purple; *Marsh*, horizontal light-blue patches running into green; *Meadow* or *Pastures*, light green; *Ploughed land*, brown; *River*, dark blue; *Road*, burnt sienna; *Sand*, light-yellow ochre; *Sandbanks* under water, as sand with a little red; *Stone* and *brick buildings*, carmine; *Trees* in masses, yellowish; *Trees*, single, dark green; *Troops*, colour of the uniform; *Water*, blue, with shading on the shore; *Wooden buildings*, sepia.

(17.) The list of conventional signs we have given is by no means complete, but it is quite sufficient for ordinary purposes. We might add a few military signs.

FIG. 2.



When, however, objects are met with in a survey for which we do not know of any conventional sign, we make in the margin of the drawing a list of the peculiar signs we adopt for the occasion.

(18.) We shall conclude this section by some hints on the drawing of conventional signs.

Roads should always be drawn towards the draughtsman to insure to their sides an equal thickness throughout. The chief thing to keep in mind is the parallelism of these sides, as roads generally retain the same width except near the entrance of towns, where they widen, and in mountains, where they become narrow. The parallelism can only be obtained by drawing the left side first to serve as a guide for the right one.

Railroads, being chiefly straight, are better drawn with a ruler; the two sides should be exactly parallel and rather thick; they are always narrower than roads.

When two or more roads meet to form a crossing, the sides should not intersect at an acute angle, but should be rounded off.

Rivers have the side nearest to the light made thicker. When wide enough they are filled with thin lines, parallel to the winding of the banks, kept closer near the sides.

Lakes, ponds, and seas are drawn in the same manner, and the thin lines may be either horizontal or parallel to the shore.

There are a great many ways of representing trees and woods. In engraved plans (Plate XXXIII.) they are done as in the conventional signs. Sometimes on the sides of roads they are figured by thick dots. In sketches, woods are represented in patches somewhat as in landscape drawing, the light being, as usual, supposed to come from the upper, left-hand corner.

Gardens are enclosed by walls or hedges; the interior is divided into small squares, with white spaces to figure the alleys, and the squares are filled with etchings.

Buildings, when not coloured red, are filled with etchings, but on a scale less than 6 inches to the mile they are made quite black. When filled with etching, the sides farther from the light are made thick.

§ II.

Representation of the Ground.

(19.) When the ground is horizontal, the signs which we have given are quite sufficient to represent the country by the outline and relative position of every object; but when the ground is no longer level, new signs become indispensable to complete the plan, so as to make it convey exact ideas of the hills, valleys, ravines, and other undulations of the surface. It is most essential that, by means of such plan, an officer should at once be able to ascertain the position of commanding points, and decide whether a spot is accessible or not to cavalry and infantry.

A plan should therefore fulfil these two conditions:—

1. Represent the ground so as to enable us to ascertain the relative height of the different points, and to judge of the nature of the slopes.

2. Give a figure of the ground that will speak to the eyes.

The first condition requires geometrical methods, whilst the second can only be obtained by combinations of shades.

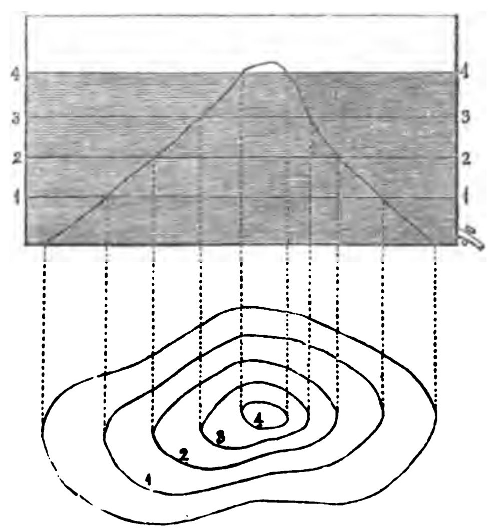
(20.) The geometrical method consists in supposing the ground intersected by horizontal planes: the projections of these intersections, or *horizontal contours*, are then transferred to the drawing at their reduced size.

To understand the principle, let us make the experiment described in Burr's treatise on surveying.

Procure a stone somewhat resembling a hill, as may frequently be found; fix it with clay to the bottom of a box provided with a plug-hole, and sufficiently large to leave a space free between the stone and its case. Fill the box with water stained with Indian ink, and let it off, by means of the plug, about a quarter of an inch in depth at several times, allowing sufficient intervals for the fluid to stain the stone in that plane, 4, 3, 2, 1, it has fallen to at the last abstraction. These stains will present a series of horizontal lines or contours, 4, 3, 2, 1, all round the surface of the stone; and if we examine the stone thus prepared, looking down upon the top, we shall see that the steepness and

the flexures of its sides will be accurately marked by these contours, which might be said to form a scale of relative steepness.

FIG. 3.



The level of the water constitutes a horizontal plane, therefore those contours are the intersections of the stone by parallel horizontal planes.

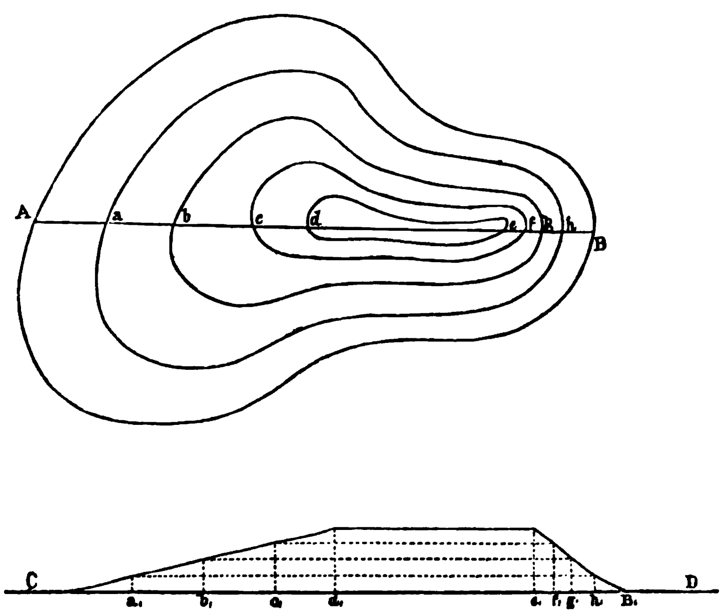
(21.) What is said of a stone may be said of a hill or of any surface, and those horizontal contours will give us a geometrical representation of the ground.

But if we come to suppose the horizontal planes of section to be equidistant, we can at once, being given the altitude of one point and the equidistance, find the altitude of any point. The inclination of the slopes may also be found by dividing this equidistance by the perpendicular common to two consecutive contours.

A profile of the ground in any direction can also be obtained: the section of the ground along the direction A B, for instance, is found (Fig. 4) by carrying on any line C D, distances C a, C b, &c., respectively equal to A a, A b, &c., and drawing through those points a, b, &c., perpendiculars representing the altitude of the contours a, b, c, &c.: the lines that connect the extremities of those perpendiculars figure

the section. Elevations may also be drawn (see Plates XXI., XXII.) by the usual method of geometry.

FIG. 4.



By diminishing the equidistance, it is clear that the description of the undulations can become very accurate, and almost mathematically exact; it will therefore vary with the scale of the plan and the nature of the country surveyed; the larger the scale, the smaller the equidistance.* This method of representing the ground answers the first condition which a plan should fulfil, and is now adopted everywhere for engineering purposes.

---

* In the Irish survey of 6 inches to the mile, it was 50 feet for cultivated parts and 100 feet for mountainous and barren districts. In France, as a rule, the ratio between the equidistance and the denominator of the scale is constant, and $= \frac{1}{2000}$, and a great advantage is thereby gained, since at whatever scale a plan is made, the same inclination will always be represented by contours equally distant. At the scale $\frac{1}{10000}$, the sections are thus 5 metres apart; at $\frac{1}{20000}$, 10 metres, and so on. In exceptional cases only is this ratio altered. Thus, for the almost level plains of Champagne, the Ordnance Survey adopted the ratio $\frac{1}{4000}$, giving an equidistance of 5 metres, at the scale $\frac{1}{20000}$.

(22.) The second condition, as we stated, can only be obtained by combinations of shade; and if the conventions we adopt in order to gain this object are made to depend upon the principle of the horizontal contours, we shall obtain the very important result of combining accuracy with expression.

Now, when we gaze upon the surrounding country, the effect of perspective presents to our eyes the apparent, instead of the real, forms; the representation should therefore be made as viewed from a point vertically above; but even then, if the sun is shining, the features will differ in the afternoon from what they were in the morning; and the effects of light and shade will not be in constant accordance with the true form.

For these reasons we are led to suppose the ground illuminated by a vertical light, as happens in a cloudy day, and if, then, we imagine ourselves placed vertically above the surface to represent, we shall perceive, as in a model, that the more level a part the brighter it is, and the steeper the acclivities of a hill, the darker they appear. The shade is thus proportionate to the steepness of the slopes.

(23.) This effect of shade might be produced by adapting the equidistance to the scale and to the nature of the ground, so as to have contours close enough to give a shading; but the tracing of those contours on the ground would be too long for military purposes. If, on the other hand, we insert a sufficient number of lines between a few contours determined by levelling, as in Plate VIII., the ground is not faithfully represented. The surface between two such contours has not always a uniform slope, and the space between two contours of the drawing would be a mean surface either enveloping or intersecting the real one. The execution would be tedious and difficult.

Hence methods have been devised, some having regard to expression only, others combining expression with accuracy. We may classify them under three heads, the English system, the French system, and the German system.

(24.) English systems are of two kinds; the horizontal style and the vertical style, both of which have only expression in view.

In the *horizontal style* the ground is figured by horizontal strokes more or less thick and close, and the altitude of the chief points is

given in figures. Plates IX., X., and XIX. illustrate two varieties of this method, which leaves a wide margin for artistical skill.

At the Royal Military College the horizontal method is now employed almost exclusively. From XI. to XVII. we give the series of progressive plates drawn by Major Petley for the instruction of the cadets. They are a most excellent imitation of nature, and there is no doubt that for military sketches this method is preferable to all others, on account of its simplicity and rapidity of execution. Plate XVIII., executed by Captain Richards, Instructor in Military Drawing at Sandhurst, and formerly a pupil of Major Petley, is as good a specimen of a military sketch as could be wished for.

There will, however, always be two defects in all the varieties of horizontal style. The roads, in hilly ground, deviate but little from the horizontal plane, and are not easily distinguished from the horizontal strokes to which they remain parallel. Again, the extreme strokes at the summit and base of a hill cannot be melted into the soft appearance of natural shade.

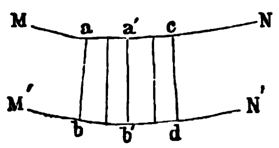
(25.) In the *vertical style* the strokes are intended to represent the course which water would follow on its descent along the slopes; but in this country it has only been employed to obtain expression, and it is not more accurate than the other style, and requires more time. Plate XXIV. is part of the military sketch made in the Crimea by the officers of the Quartermaster-General's Department. Sometimes the vertical hachures are inserted between horizontal contours, but without any law and any regard to equidistance.

Colonel Jackson, in his work on military surveying, very justly observes, "that the uncertain application of conventional rules, such as regular plan drawing, does a vast deal of mischief; and there is great reason to regret that such a diversity of style should be tolerated in this country. Thus, when an extensive district is to be sketched, upon which several individuals are required to be employed, it becomes impossible to unite their sketches so as to form a complete whole; nor can it be determined whose portion contains the most elevated ground." The remedy is nevertheless simple enough. Let the Council of Military Education fix upon a system and recommend it to Sandhurst and Woolwich.

(26.) In the *French system* the hachures are traced perpendicular to the contours, so that the equidistance compared with the length of these hachures will at once give the ratio of the slope. The original contours must, therefore, be preserved on the plan, and the proper effect of light and shade is produced as follows:—

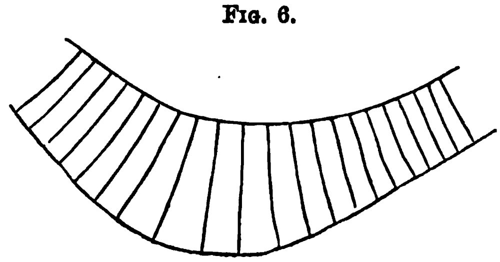
M N, M′ N′, (Fig. 5) being the contours given, the hachures a b, c d

FIG. 5.



are drawn at a distance, a c=c b; the square they form is then divided into two equal parts by a′ b′, and the rectangles a b′, a′ d arising therefrom are again divided into two. By this process the hachures are at a distance from each other = ¼ of their length, and in the practice the etching is thus expeditiously done.

FIG. 6.



Should not the contours be parallel (Fig. 6) the hachures are drawn so as to meet them at right-angles.

This, however, becomes difficult when the contours are far apart, and beginners will find it more easy to pencil intermediate contours in sufficient number to have them nearly parallel, and the hachures are afterwards kept at the proper interval. When the distance between the contours is very small, it becomes impossible to draw three hachures in the square; they are then made thicker and kept at equal intervals. The effect of shade they produce will thus harmonize with those of less rapid slopes. This should be done as soon as the

distance of the contour is less than about $\frac{1}{10}$ of an inch, and the smaller this distance the thicker the etched lines should be.

Fig. 9.

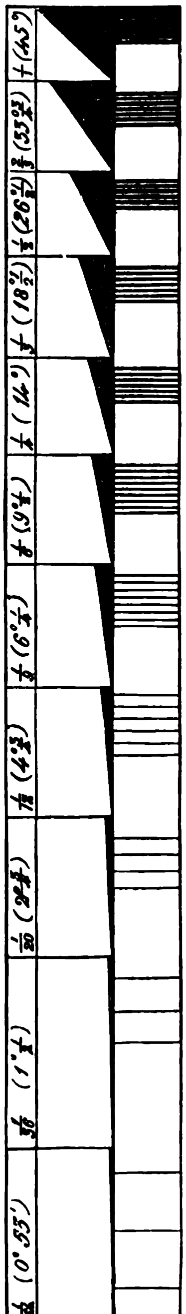
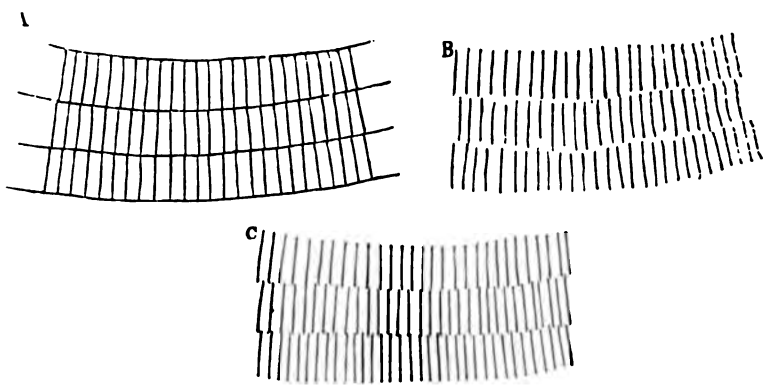


Fig. 7.

(27.) In order to preserve on the drawing the traces of the original contours, which are always useful to find altitudes, the hachures of a slice should not be the continuation of those above (A), but should be made to correspond to the intervals of the slice immediately above; and to avoid the bad effect (B) produced by lighter spots, they should be exactly terminated at the contour (C). (Fig. 8.)

Fig. 8.

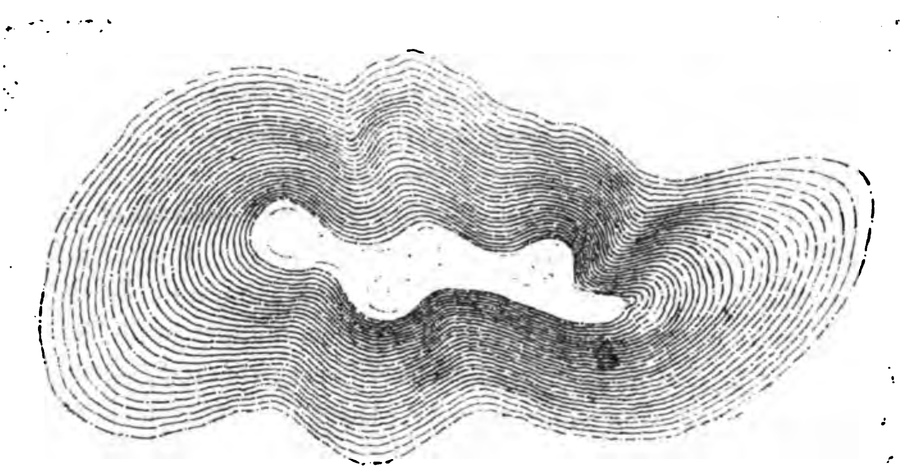


(28.) In order to secure an uniform scale of shade for all plans, scales of thickness or *diapasons* have been adopted. In the diapason of the Ordnance Map the ratio of black to white is (Fig. 9) equal to the tangent of the slope multiplied by $\frac{3}{2}$. For a slope of 45 degrees the proportion of black to white is thus 3 : 2. All slopes steeper than 45° are represented as escarpments.

The French system, we have said, combines accuracy

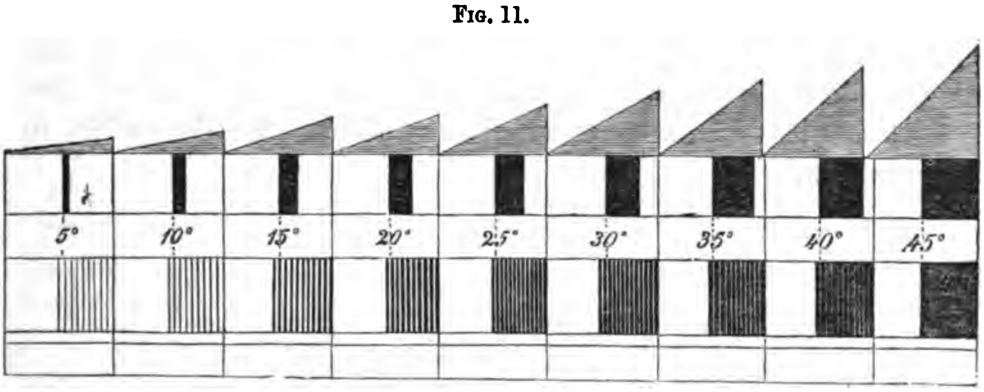
with expression, but is not expeditious. The horizontal style, on the contrary, sacrifices accuracy to expression, and is expeditious: its defect might easily be remedied by representing the original contours by strokes and dots, either as in the annexed diagram, or in some similar way. For engraved map, however, the vertical style will always be preferable.

Fig. 10.



(29.) In the German system the hachures are also perpendicular to the normal contours with or without reference to their equidistance. In the system of Lehmann, no regard is paid to the equidistance, and

Fig. 11.



the slopes are measured by the angle they form with the margin. The diapason of Lehmann gives, therefore, the length and thickness of the hachures from 5 to 6 degrees up to 45 degrees. The latter slope, being impracticable to armies, he represents by absolute black. The ratio of black to white is equal to the ratio of the angle of a slope to its supplement to 45 degrees. Thus, for the slope of 35 degrees, the thickness of the hachures is so regulated as to give a tint in which the black is to the white as 35 : 10 or 7 : 2. In this method the features of the ground are strongly marked, but the tints are too dark, and it is often difficult to read the small writing and see the details.

In other German diapasons the maximum of shade is taken for 60 degrees, but these methods requiring the measurement of every angle are too long in practice.

(30.) Besides these three systems, there are other methods of shading hills. Brushing with Indian ink is one of them; but it is not susceptible of great accuracy, and is only employed for rough sketches.

To give more accentuation to the features, oblique light has been had recourse to, but it is impossible to represent the real steepness of a slope, since the same slope may be placed in a thousand different positions as regards the direction of light: hence the same slope is differently shaded: it must also be observed that the horizontal surface has to be shaded, and the effect is no longer natural.

Plates XXV. and XXVI. are examples of shading extracted from the course of Mr. Bardin, lately Professor of Topography at the Imperial Polytechnic School of France.

Perspective has also been tried in combination with a horizontal projection, as may be seen in old plans (Plate XXVII.), but this method of bird's-eye view drawing is too inaccurate, and it is now confined to those popular maps which are published for the million in time of war.

§ III.

Features of the ground.

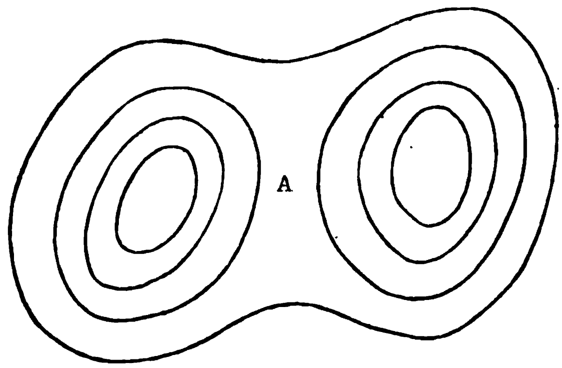
(31.) The undulations of the ground may be reduced to a few fundamental forms, whether we consider a large extent of the earth's surface or a small area. Looking at a continent or an island, we observe that the ground rises from the shore up to a chain of mountains, which separates the whole surface into two general slopes or *watersheds.* Each of these watersheds is subdivided into secondary surfaces by chains either perpendicular or oblique to the first. The declivities of the adjacent chains include between them a valley. In the same manner the branches running from these chains contain valleys of less dimensions, shedding their waters in the principal valley; while they themselves receive the tributaries of the concave surfaces formed by the minor subdivisions of the branches. The *ensemble* of all the valleys which empty their water into the sea by the same mouth constitutes what is called a *basin.*

(32.) The chains of mountains vary much in character. Sometimes the two declivities of a watershed meet on a line well defined or *crest;* sometimes they are connected by a flat surface at a greater or less altitude, called *table-land,* or they may be united by two counterslopes, enclosing lakes without outlets.

(33.) The crest of a chain or *watershed-line* is generally formed of a series of summits, between which depressions, more or less deep, establish communication between the opposite sides, forming what is called a col or pass.

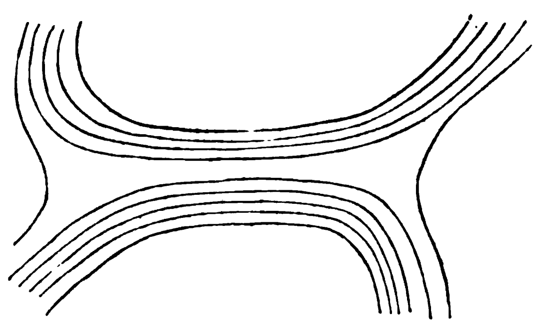
A *col,* properly speaking, may be defined the highest part of the intersection of two convex surfaces; it is therefore the origin of valleys, and is horizontal.

Fig. 12.



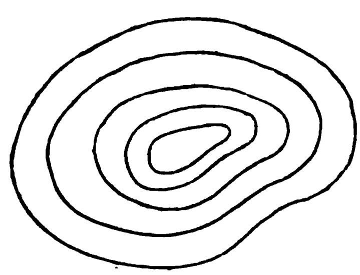
When the col is long and the adjacent heights steep, it becomes a *defile.* The defile, however, may also be found along the base of mountains.

Fig. 13.



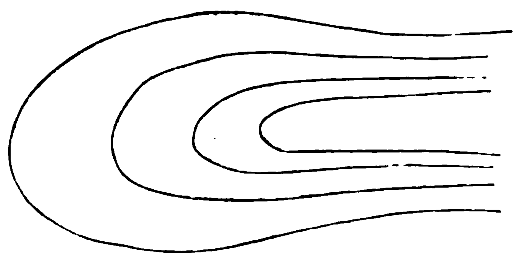
(34.) The name of *hills* applies to mountains of minor elevation, more or less conical, and without any apparent crest.

Fig. 14.



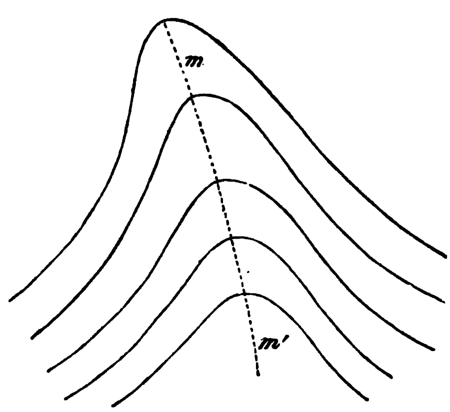
Counterforts (croupes) are indentures found in ranges of hills ; their flanks belong to two adjacent valleys.

Fig. 15.



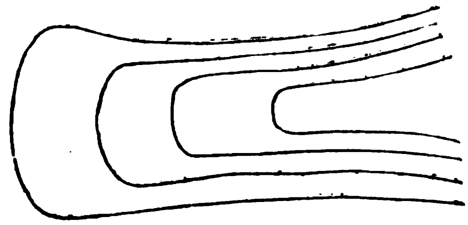
(35.) A *valley* is the concave surface formed by two declivities or flanks; the line m m' of less inclination according to which the slopes meet is called the *thalweg*.

Fig. 16.



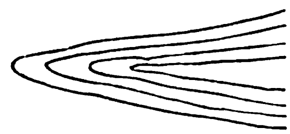
When the thalweg is but slightly sloping the valley becomes a *dale*.

Fig. 17.



When the flanks are very steep and close they form a *ravine*.

FIG. 18.



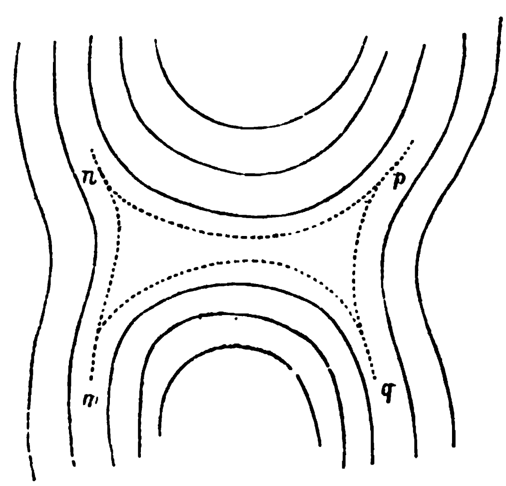
In Plate V. we have combined these chief undulations:—thus A, *a*, *a*, *a*, are cols; G, G, defiles; B, B, *b*, *b*, hills; C, C, C, counterforts; D, D, valleys; E, E, vales; F, F, ravines; H, H, table-lands.

(36.) In drawing the hachures between the horizontal contours, we should pay attention to the following remarks:—

The extreme hachures of a slope should be terminated as fine as possible, in order to render softer the melting of the shade into the white of the paper, this conformably to nature, where we see no slope beginning or ending abruptly.

No hachure should be drawn on the direction itself of a thalweg or a watershed-line, because a continuous line would strike the eye unnaturally, as those directions have the least inclination. For a similar reason, in ravines the extreme hachures of the flanks should not meet, but should end in a fine point.

FIG. 19.

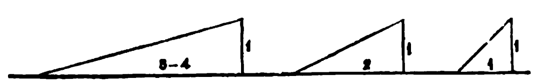


In a col the little horizontal table-land is left in blank, and it is limited by drawing the intermediary contours mn, mq, qp, pn (Fig. 19)

on which we arrest the point of the extreme hachures. (See Plates XX., XXI., XXII., XXIII.)

(37.) With the rules laid down we are enabled to figure *precisely* the forms of the ground, since the direction of the hachures indicates that of the slopes, whilst their length or distance compared to the *equidistance* permits us to measure the real inclination of the latter. The acclivities have been divided into three classes: those practicable for carriages and inclined to the horizon at not more than 15°; those practicable for cavalry limited to 30°; and those practicable only for infantry and limited to 45°. From what precedes, the student will easily perceive on a plan to which class belong the various undulations thereon figured. When the length of the hachure is less than 3 or 4 times that of the *equidistance*, the slope is no longer passable for

FIG. 20.



artillery. When it is less than twice the *equidistance*, the acclivity is too rapid for cavalry, and when both lengths are equal, we know that it is the steepest slope practicable for infantry.

§ IV.

Copy and Reduction of Plans.

(38.) The first step in Topography is to become thoroughly acquainted with the drawing of plans, a knowledge only acquired by practice. Copying plans ready-made renders one familiar both with the conventional signs and with the ordinary features of the ground. This part is the most difficult; but once mastered, surveying becomes comparatively easy.

(39.) When a plan is to be copied on the same scale, its surface is divided into squares or rectangles (Plate XXXI.), which will be so much the smaller as the details will happen to be more minute. An equal frame is then drawn, and its surface is divided into the same number of squares as the model (Plate XXVIII.). The details are then copied

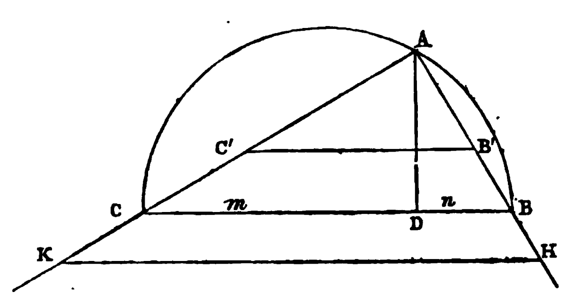
square by square. It is advisable to avoid the use of compasses, and to transfer everything at sight, for it is the only way to learn how to draw rapidly and accurately. Should a square contain too many details, the diagonals may be drawn to give further assistance, or its surface may be subdivided into smaller squares. If the model must not be soiled, we cover it with glass, and trace the square on the glass. We begin with the pencil and draw the roads, rivers, buildings, walls, gardens, rocks, hedges, &c.; then we ink these details in the following order:—roads, rivers, buildings, walls, footpaths, gardens, ditches, direction of hedges, divisions of culture, and rocks.

When this is done, we trace in pencil the horizontal contour (Plate XXIX.). Next we shade the hills, either in the horizontal or vertical style (Plate XXX.). The copy is afterwards completed by figuring the woods, marshes, meadows, or colouring them, as the case may be. The names are then written, together with the altitude of the chief points, and the scale is either made or named under the frame.

(40.) If the copy is to be made on a different scale, say twice smaller, a frame is drawn with sides twice smaller than the model, and its surface is divided into the same number of squares. We proceed then as before, with this exception, that we copy one contour out of two, three, four, &c., when the new scale is twice, three times, four times, &c., smaller.

(41.) If the area of the copy must bear a certain ratio to that of the given plan, say $m : n$ for instance, we proceed as follows:—Draw the two

FIG. 21.



lines C D, D B, so that (Fig. 21) $CD : DB :: m : n$. On B C describe a

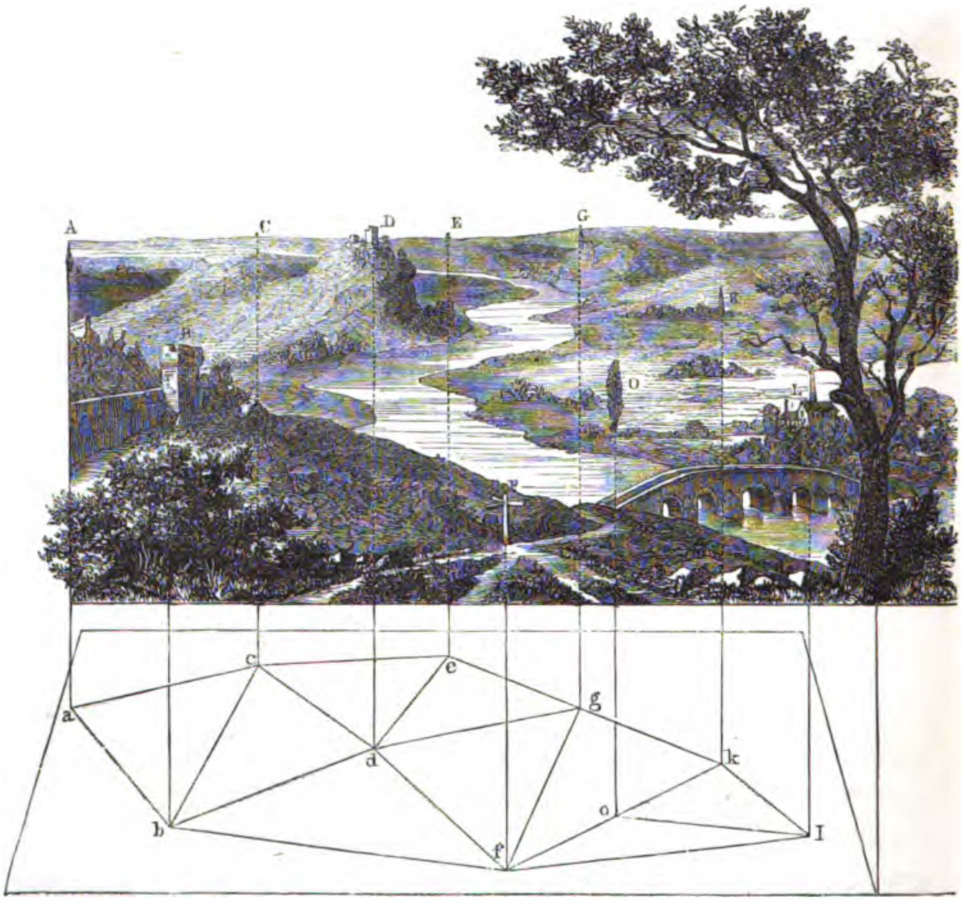
semicircle, erect D A perpendicular to B C, then A C′ : A B′ : : *m* : *n*. On the direction A B take A H equal to the side of the model, draw through H a parallel to B C, and A K will be the corresponding side in the copy. The second side will be found in the same manner. Having then traced the frame, we divide its surface in the same number of squares as the model, and proceed as usual. The scale of the copy is easily obtained. Take A C′ equal to one inch, draw C′ B′ parallel to C B, and the distance A B′, measured on the scale of the model, will show what one inch represents in the copy.

CHAPTER III.

TRIANGULATION.

(42.) We have said (6) that planimetry consists in making a reduced image of the projections of the various points of the surface of the ground. In practice, however, we make a selection among these points, and begin by considering only the chief ones, such as steeples, chimneys, isolated trees, and other objects easy to recognise at all times, and we imagine them united by straight lines. The projections of those lines constitute a series of triangles forming a sort of netting (canvas) (Fig. 22), between the sides of which all the other details are contained;

Fig. 22.



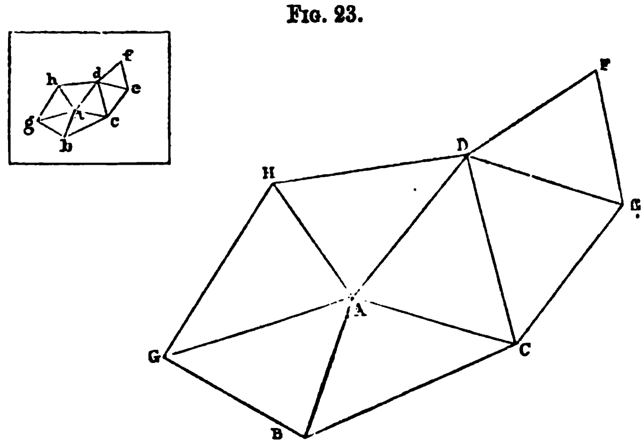
and the first problem of planimetry, *contained* in the 18th proposition of Euclid (lib. vi.), will be to make a figure similar to that *canvas*, an operation called *triangulation:* the second problem will again be to make figures similar to those contained in these triangles, an operation called the *filling in of details.*

Thus, the points A, B, C, D, being projected in a, b, c, d, on the horizontal plane (Fig. 22), the figure a b c d is called the canvas, and all that is contained in every one of the triangles, a b c, c b d, &c., constitute the details.

It is readily understood that the triangles of the *canvas* must be more or less numerous according as the scale of the plan is small or great, so that the details they contain may be represented afterwards in their relative positions without any appreciable error.

(43.) Since, to construct a triangle, we require to know either three sides, or two sides and one angle, or one side and two angles, it follows that three different methods may be adopted to make a survey. In military topography, however, where expedition is a most essential condition, the methods founded upon the measure of three sides, or of two sides and one angle, are rejected as too long, and the following process is preferred (Fig. 23):—A side, A B, is first measured ac-

FIG. 23.



curately, and its projection is drawn at the scale in a b; then in observing the angles C A B, A B C, the elements of the triangle A B C are obtained and a b c is constructed on a b, similar to A B C. The sides A C, B C, being thus known, we go on measuring the angles

D A C, A C D, and the triangle a c d is made similar to A C D. Again, the angles C D E, E C D, furnish the triangle c d e; and so on, measuring the angles.

This line, A B, the only one we measure, is called the *base*. It is selected, as much as possible in the middle of the surface to survey, and such that from its extremities several important points may be seen. In that manner several angles may be observed at a same station: thus while at A, the angles B A C, C A D, D A H, H A B, B A B, are measured.

(44.) The form of the triangles is not arbitrary, they should be as nearly equilateral as possible, for if an angle were very acute the slightest error in the measurement of the others, in A for instance (Fig. 24), would cause a great difference in the position of the vertex

FIG. 24.

C. Besides, it is very difficult to see exactly where two lines meet at so small an angle. The equilateral form possesses the further advantage of covering a given surface with a less number of triangles, and thereby simplifying the labour.

(45.) The maximum length of their sides, as well as that of the base, depends upon the approximation with which the angles are measured, and upon the scale adopted. The students acquainted with trigonometry will find the length by means of the formula $l = \frac{\varepsilon}{2 \sin a}$ in which l represents the length, and ε the error depending on the scale or uncertainty of reading (9), and a the error committed in observing the angles, varying with the instruments employed. We give a few results at the end of the chapter.

(46.) Starting from a base, we have said that we draw triangles similar to those of the ground by means of the angles: this can be done either by calculation or construction. Trigonometry enables us, when knowing two angles and one side, to calculate every dimension of a triangle. Having, therefore, measured the base and all the angles, we

can calculate all the sides, and then draw them at the scale by the process of geometry. But this method, certainly the most accurate for surveys of importance and precision, is altogether set aside in military surveys on account of the time it requires. The second mode, which is the one that should be adopted, consists in laying down or protracting the angles as soon as they are measured.

(47.) We need no field-book to write down the various measures, as is often recommended, but we at once draw or PLOT, as it is called, what we observe. The only book that we may carry will serve to take note of the statistical, political, and military information (139) which we require.

Let it be remembered that it is only by plotting on the ground itself that an officer will acquire the habit of sketching rapidly the features of a country. In one case only (122) may we take notes of some measurement; but even then it is not indispensable.

When the canvas has been plotted, the details are filled in by a similar process, viz., by measuring distances and angles; and it is therefore logical that we should successively determine upon the instruments destined for that purpose.

Error in the Angle.	Scale—Number of Inches to the Mile.	Maximum Length of Sides in Yards.
1′	2	15126
	4	7563
	6	5042
15′	2	1008
	4	504
	6	336
30′	2	504
	4	252
	6	168
1°	2	252
	4	126
	6	84

CHAPTER IV.

DISTANCES.

(48.) A *chain*, or a rope, 100 feet long, divided into a hundred links, together with a set of 10 arrows, is sufficient to measure every distance in a survey.

Two persons, the leader and the follower, are required to take the measure. The leader starts with the arrows in his left hand, and one end of the chain in his right, while the follower, remaining at the point of starting, directs the leader in the proper line and makes him stretch the chain. The leader then plants an arrow, and starts afresh as before, whilst the follower comes up to the first arrow. The second arrow is planted by the leader, and the first taken up by the follower; and so on. When the 10 arrows have been used, the distance measured is equal to $10 \times 100 = 1000$ feet, which are noted, and the follower returns the arrows to the leader to continue the operation.

The chain should be kept as horizontal as possible, since the measure required is that of the horizontal distance. When the ground is not level, the chain being kept horizontal, the effect of gravity will curve it a little, therefore shorten its length, and the distance measured will be too great. It is, therefore, better to put the chain flat on the ground and to reduce the distance thus found to the horizontal plane. The chain used by civil engineers, or Gunter chain, is only 22 yards long. It is very convenient where the contents of an estate are to be given in acres, because ten chains in length by one in breadth measure exactly one acre.

(49.) Pacing is generally resorted to, while filling in the details of a survey (52). The trotting of a horse might also (53) be made available.

Distances can also be measured by time, when we have previously ascertained over how many yards we walk or ride in a given time.

This is not of rare occurrence in the field. When distances are measured by pacing or riding, a correction is necessary, owing to the lengthening caused by the acclivities, and the turnings of roads: on slightly uneven ground we subtract $\frac{1}{7}$ of the distance found, and $\frac{1}{5}$ when the undulations are more important.

When the atmosphere is calm, sound travels at the rate of 1118 feet per second, therefore, a musket fired may serve to measure a distance; a watch gives the number of seconds elapsed between the instant the light is seen and that when the report is heard: that number multiplied by 1118 feet gives very approximately the distance.

If no watch is to be had, the time is obtained by counting the pulsations of an artery. A sound pulse averages from 75 to 80 in a minute.

Distances may even be guessed by observing that in clear weather the windows of a house can be counted at 4000 yards. Horses and men appear as dots at 2200 yards, a horse is clearly seen at 1200 yards, the movements of men are perceived at 800 yards, and the head is distinctly visible at 400 yards.

Several instruments, known under the name of "stadia," have been constructed for the purpose of measuring distances; but as the means explained above are amply sufficient for all military surveys, we shall not enter into their description, and we refer the students to any treatise on mathematical instruments.

(50.) The distances once measured must be drawn at the scale; we must therefore illustrate, by a few examples, how to construct one.

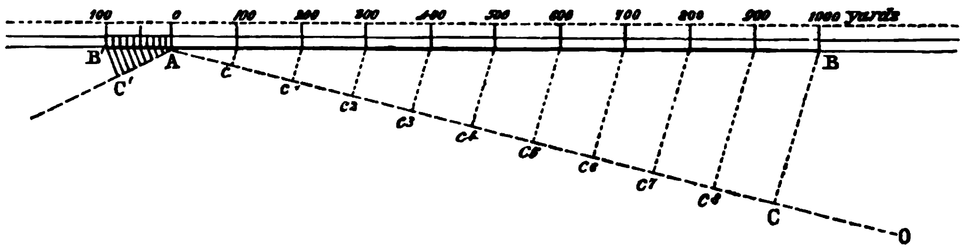
Let us begin with a scale of 6 inches to the mile.

Since 6 inches represent 1760 yards, 1000 yards will be represented by $\frac{6 \times 1000}{1760}$ or 3·4 inches. If, therefore, we take a line 3·4 inches long, and divide it into ten equal parts, each part will represent 100 yards; if these parts are farther subdivided into ten, each new subdivision will represent 10 yards. To construct the scale, draw in pencil three parallel lines, about $\frac{1}{15}$ of an inch apart, and mark off on the bottom line A B=3·4 inches. Divide A B into ten parts. This is done by drawing through A a line A O, making with A B any angle, marking

off any length A C, and taking it ten times from A to C: joining C B, and through the points of divisions c_8, c_7, c_6 &c., drawing parallels to C B, these will divide A B into ten equal parts. Produce A B to the left,

FIG. 25.

Scale of Six Inches to One Mile.



take A B equal to one part, and by the same process divide it into ten. Ink the two bottom lines; through the points of division draw perpendicular to them, limiting their lengths to the top line for the primary divisions, and the middle one for the subdivisions; number the divisions, and write on the right the unit of measure which in this case is "yard."

This scale is used on the paper, by means of a pair of compasses, as we would employ a chain or a yard. Suppose we want to take off 470 yards; place one point of the compasses on division 400, and the other point on the 7th subdivision: the length included between the two points is 470 yards. Conversely, to value a dimension of the drawing, take it with the compass, place one point on the division 0, and read the figure corresponding to the right point. If this point does not fall exactly on a division, move it to the left until the right point coincides with the nearest division, then the left point will mark the required subdivision.

FIG. 26.

Scale of Six Inches to One Mile.

If the chain of 22 yards is the instrument actually employed to measure the distances on the ground, it is preferable to construct the scale of 6 inches to the mile as follows (Fig. 26):—

Since 6 inches represent 1760 yards or 80 chains, therefore, 60 chains $=\frac{6\times 60}{80}=4\cdot 5$ inches. Take a length of 4·5 inches, divide it into six equal parts; and if we subdivide the left part into ten, we shall have subdivisions representing single chains.

To construct a scale of 2 inches to the mile. In this case we cannot show parts representing 10 yards each. Since 2 inches correspond to 1760 yards, 4000 yards are represented by $\frac{2\times 4000}{1760}=4\cdot 54$ inches. Divide this length into 4 parts (Fig. 27), they will show 1000 yards: dividing into 10 we have subdivisions of 100 yards.

Fig. 27.

Scale of Two Inches to One Mile.

(51.) To construct a scale $\frac{1}{20000}$, we find that a distance of 3000 yards is to be represented by $\frac{3000\times 36}{20000}=5\cdot 4$ inches (Fig. 28). Divide the length into three parts, we shall have divisions of 1000 yards, and subdivisions of 100 yards.

Fig. 28.

Scale of $\frac{1}{20000}$.

(52.) Should the distance be measured by pacing, a proper scale must be constructed. Although the length of a pace is not a constant magnitude, we may assume that in general 2000 paces make up a mile. If the plan is to be made on a scale of 4 inches to the mile, then since 4 inches represent 2000 paces, we shall have divisions of 100 paces

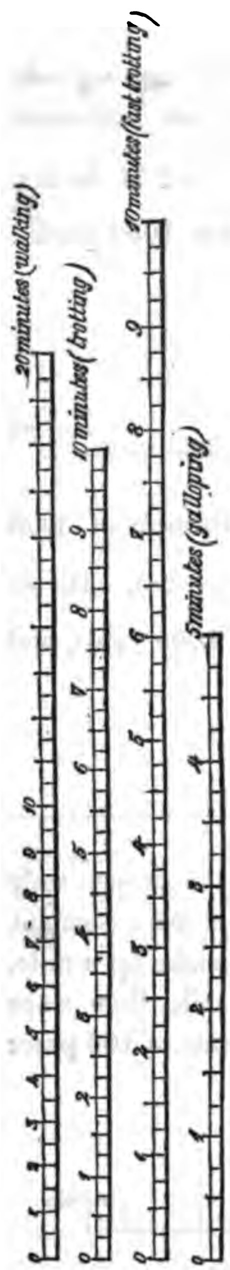
Fig. 29.

Scale of Four Inches to One Mile.

(Fig. 29), and subdivisions of 10 paces, in dividing these 4 inches

into twenty parts, and subdividing one part again into ten. If 2000 of our paces do not make a mile, we can ascertain how many do by walking over a distance which has been measured.

Fig. 30.
Scale of $\frac{1}{15000}$.



(53.) Scales are also made for distances measured by time.

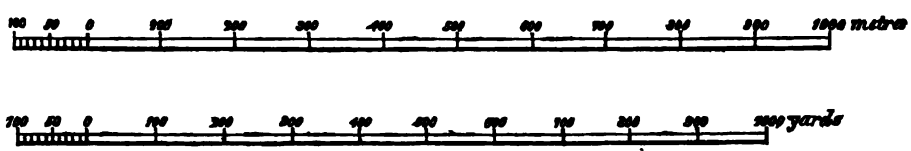
Suppose, for instance, that we employ either the pace, the trot, or the gallop of a horse, and that we want to construct a scale of $\frac{1}{15000}$. We first ascertain at what rate our horse proceeds: in general a horse goes over 100 yards walking, 180 yards at a moderate trot, 230 yards at a fast trot, and 280 yards at a gallop in one minute.

We then calculate that in walking 20 minutes the horse goes over 2000 yards, a distance represented by $\frac{2000 \times 36}{15000} = 4{\cdot}8$ inches; that at a moderate trot and fast trot he goes in ten minutes over 1800 and 2300 yards respectively distances represented by $\frac{2800 \times 36}{15000} = 4{\cdot}3$ and $\frac{2300 \times 36}{15000} = 5{\cdot}5$ inches; and that at a gallop he makes 2800 yards in ten minutes, or 1400 in five, a distance represented by 3·3 inches. These lengths, 4·8, 4·3, 5·5, and 3·3 being respectively divided into twenty, ten, and five parts, will give us parts representing one minute.

(54.) In examining foreign plans it is found very useful to construct for them a scale in English measures. Suppose that it is a French plan, the unit of measure of which is the metre. If the representative fraction of this plan is given, we have only to proceed as in a former example (51); but if this fraction is not given, we take off on the scale any distance, say 1000 metres. Let that distance measure 3·9 inches, then we know

that 3·9 inches represent 1000 metres (Fig. 31), or $1000 \times 3{\cdot}28$ English feet $=3280$ feet $=1093{\cdot}33$ yards. It is now easy to find that 1000 yards are represented by $\frac{1000 \times 3{\cdot}9}{1093{\cdot}33} = 3{\cdot}56$ inches, and we proceed as in former examples.

FIG. 31.



(55.) It has been said before (48) that the distances obtained from direct measurement on an inclined ground should be reduced to the horizontal plane, inasmuch as their projection only is required. For the student familiar with trigonometry, this reduction offers no difficulty, since the projection is equal to the distance measured multiplied by the cosine of the angle of inclination. As tables of sines are not always at hand, we give here the reduction ready made. (See 115.)

DISTANCE ACTUALLY MEASURED 100 YARDS.

ANGLE OF INCLINATION.	DISTANCE REDUCED.
0°	100
5	99·6195
10	98·4808
15	96·5926
20	93·9693
25	90·6308
30	86·6025
35	81·9152
40	76·6045
45	70·7107

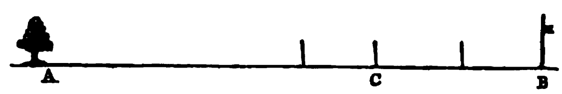
(56.) Two points determine a direction, but when they are some-

what distant, it becomes a difficult matter to measure along that direction, unless it be properly traced or signalled. We shall therefore begin with the following problem :—

To mark on the ground the direction between two given points, A *and* B.

1st. If one of these points, A, is accessible, an observer takes his station at it, whilst another (Fig. 32), C, plants staves in the

FIG. 32.



direction of B, so as to make them coincide with the vertical of B, which is ascertained by A, who signals to C with the hand until the coincidence takes place.

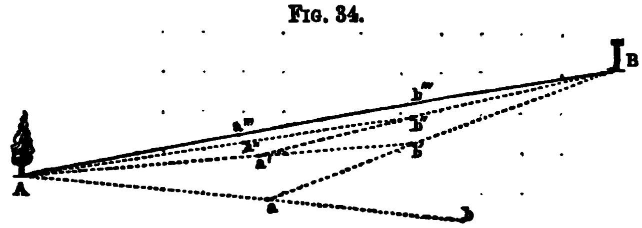
2nd. If the direction between A and B is to be produced, we place a staff in C where the vertical of B masks that of A. (Fig. 33.)

FIG. 33.

3rd. If both points are inaccessible. (Fig. 34.)

When neither point is visible from each other, two observers, a and b, place themselves out of the direction A B, facing each other: b

FIG. 34.

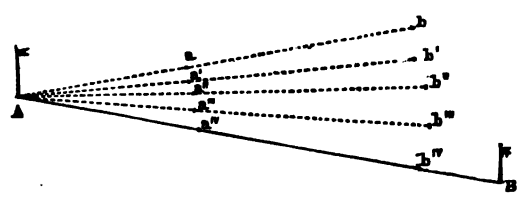


makes sign to a to move until he is in the dressing b A; then a puts in a similar manner b in the position b′ where he masks B: again, b′ moves a to a′ on the direction b′ A; a′ in his turn places b′ to b″; and

so on. In this manner a moment arrives when both persons respectively conceal from one another's view the points A and B: when such is the case they plant staves, and proceed as before.

If both observers are too far apart to perceive each other's signs, b places himself in the direction a A; a facing b marches towards A B;

Fig. 35.

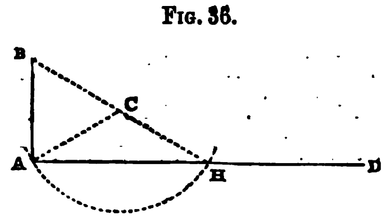


and b, by more rapid motions, keeps himself in the dressings a′ A, a″ A, &c., until he conceals B from the sight of a. Then all the points A, a^{v}, b^{v}, B, are in a line, and staves are planted as before.

Although a military survey should be executed according to the principles laid down in the former chapter, yet, as we may fail to obtain proper instruments to measure angles, it is well that an officer should understand to what advantage he can turn a mere chain (or his pace), and the following examples will familiarize him with that simple instrument:—

(57.) *To trace on the ground a perpendicular to the extremity,* A, *of a line,* A D, *which cannot be produced.*

Fig. 36.



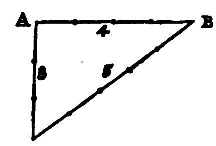
Let any point, C, be taken; chain or pace C A; trace the line C H = C A. Produce C H (56) and make C B = C H.

The line A B is the perpendicular required.

A simple process for setting off a right angle on the ground consists in making a triangle with three pieces of cord of the respective lengths

3, 4, 5, or in this proportion, placing the side 4 on the direction, A B, with which the angle is to be made, and stretching the other two until they haul together on the ends of side 4, the side 3 will give the direction at right angle with A B.

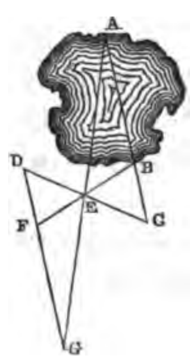
Fig. 37.



(58.) *To find the distance between two points,* A B, *one of which,* A, *is inaccessible.*

Produce A B to any point, C: through C trace C D in any direction, and bisect it in E with a staff; join E B and produce it to F, so

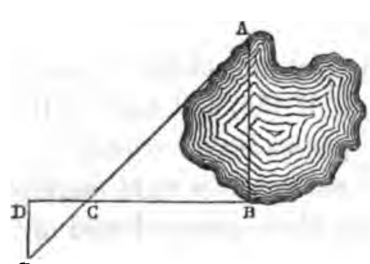
Fig. 38.



as to make E F=E B. Join D F and produce it to G, where E is seen to coincide in direction with A. Then F G=A B.

The value of A B could be found in a different manner.

Fig. 39.

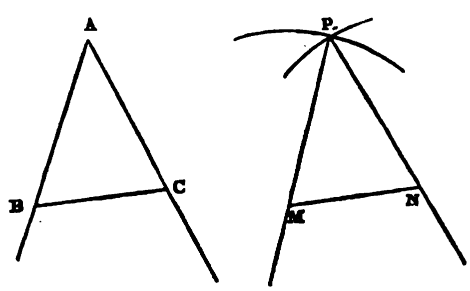


Set off B D at right angle with A B, and make it equal to 4 yards; take D C=1 yard; plant a staff in C; set off D E at right angle with D B, and mark on it the point E at which C and A are seen in a line. Then D E=$\frac{1}{4}$ A B. If the distance, A B, is great, instead of yards take chains.

(59.) *To make an angle equal to a given angle,* B.

On the sides of the angle B measure the distances B A, B C; trace B C and measure it also. Now, if the distance B C be carried on the

Fig. 40.

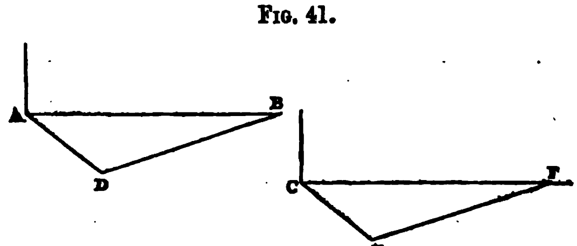


line with which the angle is to be made, on M N for instance, and circles be described from the centres M and N with A B and A C respectively as radii, the circumferences meet at a point P, and angle P M N=A B C.

(60.) *Through a given point,* C, *to draw a line parallel to a given line,* A B.

In A plant a staff, measure the length of its shadow, A D, and also the lines A B, B D. Repair to C, plant there the same staff or one

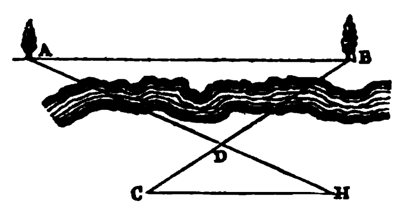
Fig. 41.



of equal length, and on its shadow, C E, construct the triangle C E F=A D B. C F is the parallel required.

If there is no sun, or if both points A and B are inaccessible, take any point, D, on the direction C B; measure C D, D B (58); produce A D, and on it measure D H, having to A D the same proportion as C D has to B D: C H will be parallel to A B.

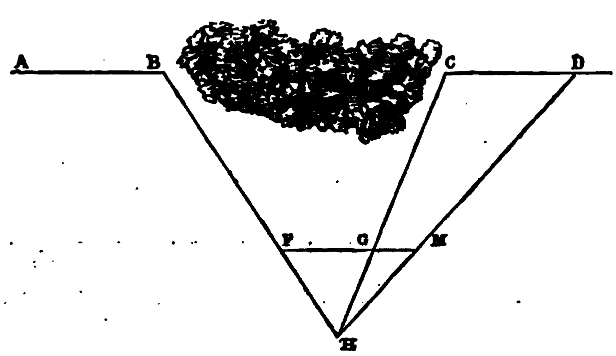
FIG. 42.



(61.) *To produce a direction,* A B, *beyond an obstacle.*

Take any point, H, trace the line B H, and also two other directions, H C, H D, on the other side of the obstacle.

FIG. 43.

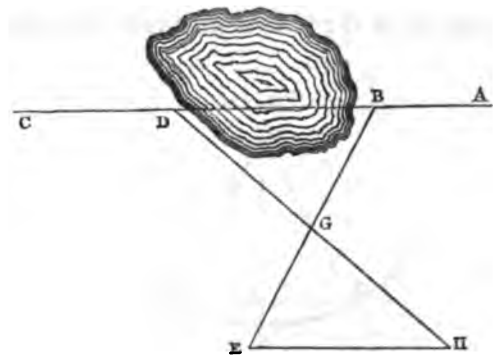


Mark any point, F, in H B, and measure H F and B F. Through F trace F M parallel (60) to A B. Measure H G and H M.

Now, if G C and M D are made the same multiple of H G and H M as B F is of F H, then C D is in the same line as A B.

When measuring along a direction A C, if an obstacle is in the way (Fig. 44), from B measure a line B E, in any direction; bisect it in G; measure G D, produce it to H, making G H = G D. The line E H is equal to B D.

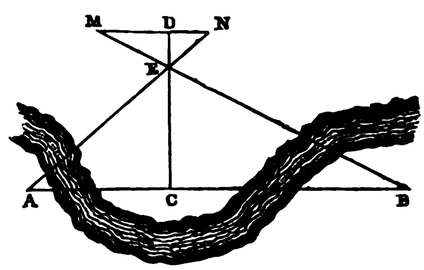
FIG. 44.



(62.) *To find the distance between two inaccessible points,* A *and* B.

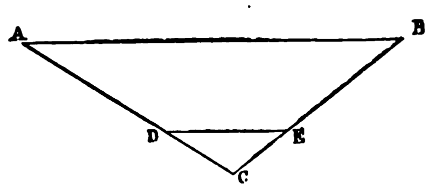
If any point, C, on the direction A B is accessible (Fig. 45), set off the perpendicular C D and take on it the distance D E, a known part. Trace M N perpendicular to C D, and on it mark the points M and N in a line with E B and E A; M N shall be the same part of A B as D E is of E C.

FIG. 45.



If there is no point accessible between A and B (Fig. 46), take any point, C. Measure the distances C A, C B (58). Take C D an exact

FIG. 46.

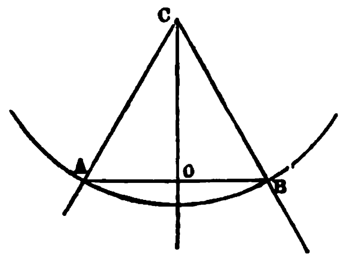


fraction of C A, and C E the same fraction of C B. Measure D E; it shall also be the same fraction of A B.

(63.) *To bisect an angle.*

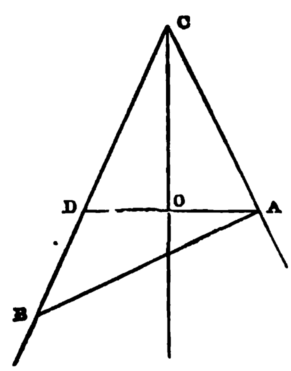
If the vertex is accessible, from it as centre describe a circle, measure the chord A B, bisect it in O; C O shall bisect the angle.

FIG. 47.



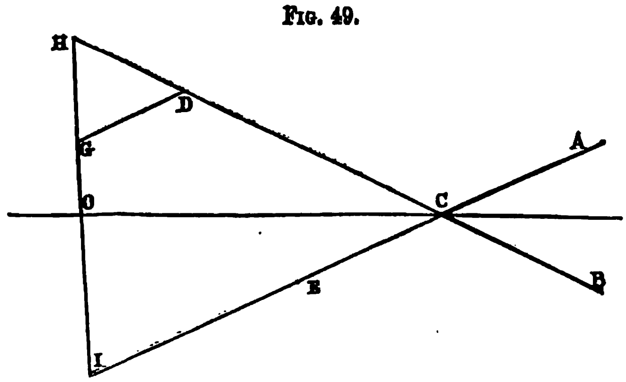
If the vertex is inaccessible (Fig. 48), trace any line, A B. Measure the angles C A B and C B A, take half their sum, and construct angle

FIG. 48.



C A D equal to it. The middle, O, of A D belongs to the line that bisects the angle C.

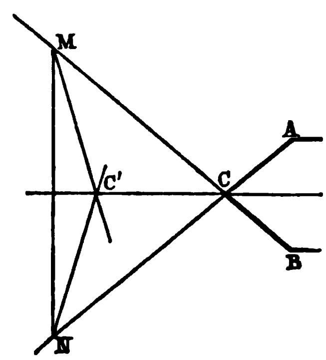
FIG. 49.



If the angle itself is inaccessible (Fig. 49), mark any two points, E and D, on the direction of the sides. Through D trace D G parallel to C E; measure equal distances, D G, D H; produce H G till it meet C E produced in I. Bisect H I in O: the line C O shall bisect the angle given.

(64.) *To determine the direction of the capital of a bastion or of any inaccessible work.*

Fig. 50.

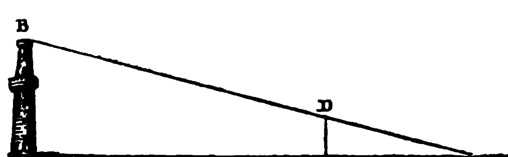


Trace any line, M N, cutting in M and N the prolongations of the faces. By means of the chain (63) bisect the angles C M N, C N M, by M C', N C'. These two lines meet in C', which belongs to the capital.

(65.) *To find the height, A B, of a building.*

Plant a staff, D E; find the position of the point O, where the eye

Fig. 51.

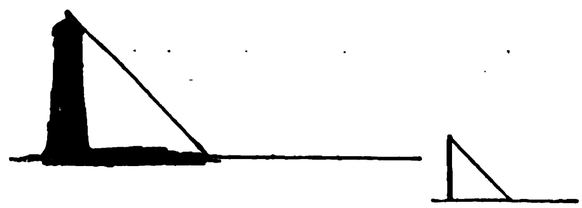


must be placed to perceive D and B in the same line with it. Measure E O, O A, and D E. A B shall be the same multiple of D E as A O is of E O.

Many other methods may be resorted to for finding the height of a building, but the most simple consists to compare the length of its

shadow with that of a pole of known height; the ratio of the two heights is the same as that of the shadows.

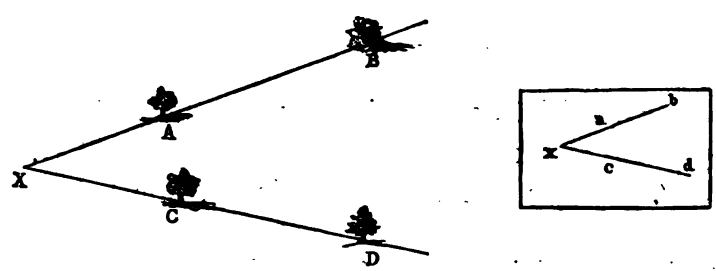
FIG. 52.



(66.) *To fix on a plan the projection of a point, having on that plan the projection of two lines.*

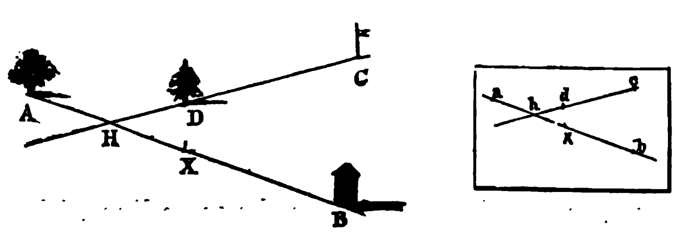
If the point X must be on both directions (Fig. 53), it is evident that its projection is at once obtained by producing the projections of the lines till they meet.

FIG. 53.



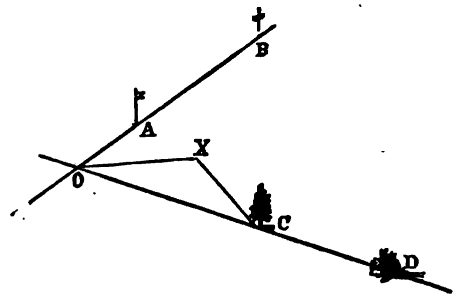
If X is on the direction of only A B (Fig. 54), produce C D on the ground till H measure H X, and draw h x at the scale on the plan.

FIG. 54.



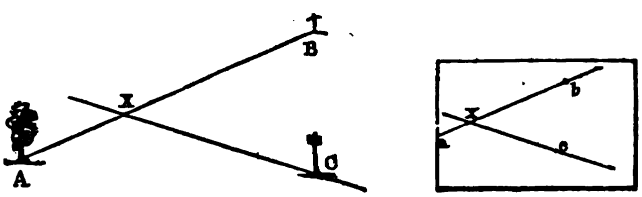
If X is on neither direction (Fig. 55), march along C D till you arrive at O on the direction B A. Measure O X and C X. On the plan the triangle o c x at the scale.

Fig. 55.



(67.) *To fix in a plan the projection of a point,* X, *having on that plan the projection of a line,* A B, *on which* X *stands, and also that of an accessible point,* C.

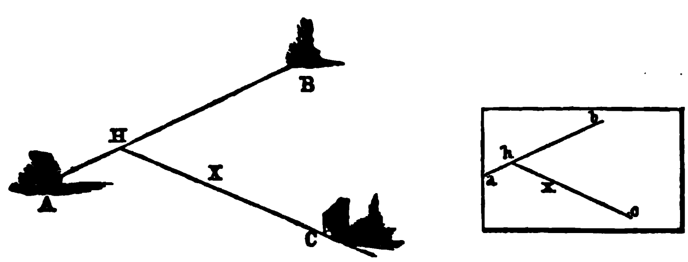
Fig. 56.



March on direction C X; measure it. On the plan, from point c as centre and distance, C x reduced at the scale, describe a circumference: it shall meet a b in the point x required.

If X is not on direction A B (Fig. 57), measure C X and X H. On

Fig. 57.

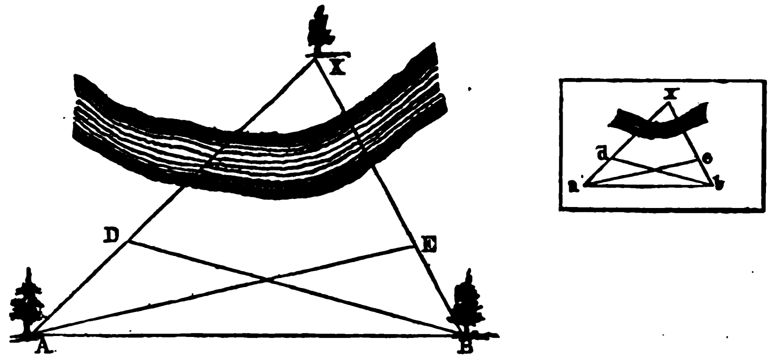


the plan determine as above the point h, and carry H X at the scale on h x.

(68.) *Two points,* A B, *being given, to fix on the plan the projection of a third,* X, *which is inaccessible.*

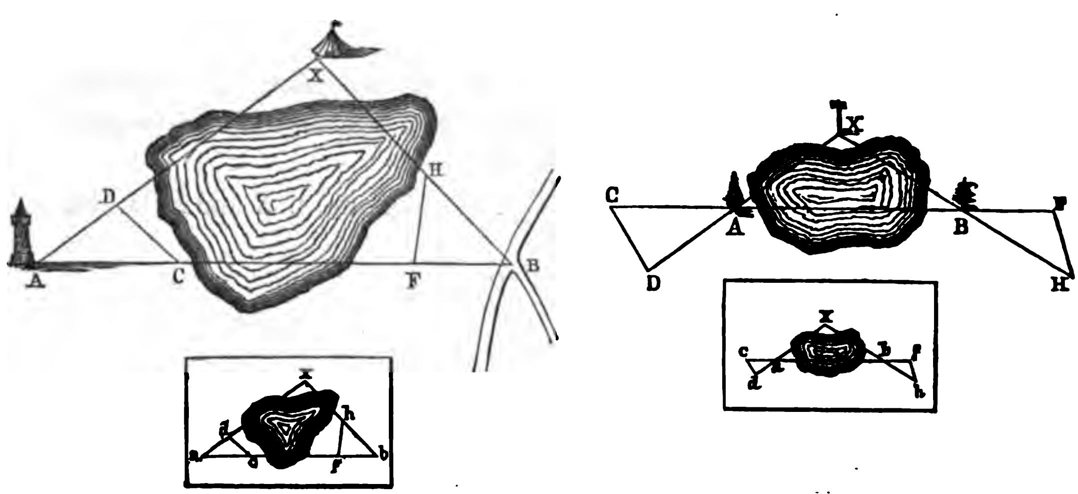
Trace the directions A X, B X, and measure A B, A D, D B, A E,

Fig. 58.



E B, and at the scale construct the triangles a d b, e b a; the intersection of the lines a d, e b, fixes the position of x.

Figs. 59 and 60.

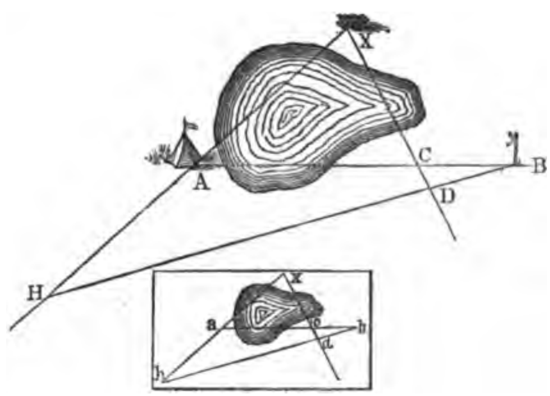


If an obstacle (Figs. 59 and 60) prevents from moving from A to B, measure any two triangles, A D C, B F H, and proceed as above.

If the point A itself is inaccessible, (Fig. 61), measure B C, produce C X to any point, D, forming with C and B a proper triangle, and on the plan construct the triangle d b c at the scale. On the ground,

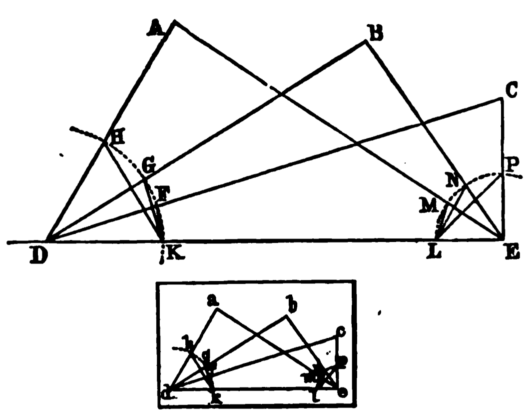
produce B D to H on the direction X A, measure D H, and carry it on the plan on d h; h a and c d produced determine the point X.

Fig. 61.



(69.) *To find the projection of several points,* A B C. (Fig. 62.) Measure a base, D E; from D and E as centres, and radii D K, L E,

Fig. 62.



describe two circumferences; measure the chords K F, K G, K H and L M, L N, L P. On the plan draw the base at the scale on d e; describe the circumferences with radii d k, l e; and by means of the radii k f, k g, k h, l m, l n, l p, complete the triangles d h k, d g k, d f k, e l p, e l m, e l n. The other sides produced determine the projections a, b, c.

(70.) A great number of instruments have been constructed to measure angles, but some are difficult to adjust and cumbersome to carry; we shall therefore confine ourselves to those which an officer can easily

carry with him in the field, or even construct himself in an emergency. We shall successively learn the use of the prismatic compass and the plane-table; and when they are thoroughly understood we shall readily employ any other, since the problems of topography are but few. Simplicity is the first condition which the instruments of a soldier should fulfil: theodolites, circumferentors, &c., are no doubt most valuable instruments in the hands of the engineer who surveys at leisure in time of peace, but for the field they are most decidedly unfit; the more numerous the adjustments, screws, glasses, &c., the more numerous the causes of error, and also the more subject the instrument is to be put out of order. However, as the box-sextant and the cross-staff are very portable, we shall conclude what we have to say on the measurement of angles by a few words on those two instruments.

CHAPTER V.

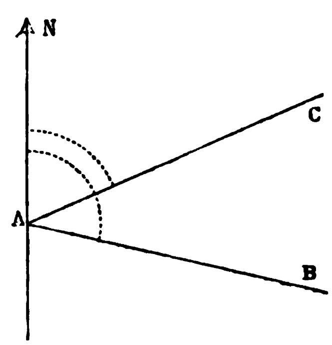
PRISMATIC COMPASS.

(71.) The *prismatic compass* is founded upon the property of the magnetic needle to constantly point to the magnetic pole, when horizontally supported on a pivot so as to turn freely.

The angle formed by a line and the magnetic meridian is called the *magnetic azimuth* of that line, and the value of this angle is called a *bearing*.

The prismatic compass is employed to take bearings, and therefore to measure the angle formed by two directions, since their angle is equal

Fig. 63.

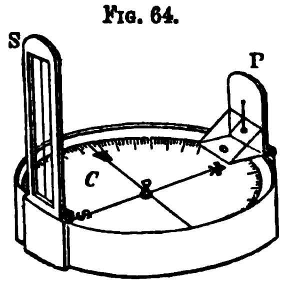


to the difference of their azimuths. The angle B A C, for instance, is equal to azimuth B A N—azimuth C A N.

(72.) In its most general form this instrument consists of a compass card C (Fig. 64), divided into half degrees from 0° to 360°, and fixed on a magnetic needle, which is supported on an agate centre, round which it turns freely. A sight-vane, S, is provided with a thread stretched along its opening; and a narrow slit, cut through the prism P, serves as the eye-sight. Both the sight-vane and the prism are mounted on a hinge-

joint, so as to be turned down flat, to permit putting the instrument in a case when not in use.

FIG. 64.



The prism can be raised or lowered in a socket, to facilitate the reading of the graduations of the card as they pass in succession before it.

A little spring, usually under the sight-vane, serves to check the vibrations of the card, when taking bearings.

To take the bearing of a direction A B, station at A, turn the prism and sight-vane up, as in the last diagram, raising or lowering the prism until the divisions of the card become distinctly visible, and hold the instrument horizontal, either in the hand or on a stand. Turn it round until the object B is seen through the slit in coincidence with the thread of the vane; check then the vibrations of the card by pressing on the spring, and the graduation of the limb that is seen to correspond to the thread gives the required bearing or magnetic azimuth of line A B.

Dark glasses are sometimes added to the prism to take azimuths of the sun, and a mirror is also found sliding along the sight-vane to reflect the image of objects much above or below the level of the eye; but they are useless for military purposes.

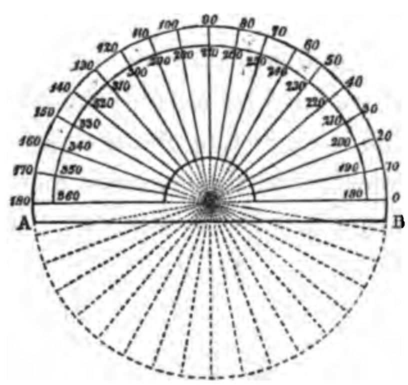
(73.) The angles measured with the prismatic compass are obtained reduced to the horizon, and this advantage, together with the portability and simplicity of the machine, renders it essentially fit for officers in the field. It is almost exclusively employed to fill in the details of extensive surveys, and also to make the triangulation of military sketches.

(74.) In order to protract the bearings several parallel lines are previously drawn across the minute, more or less close, according as the details are more or less numerous. They represent the directions of the magnetic meridians, which can be considered sensibly parallel in ordinary

surveys. An advantageous contrivance consists in drawing them at intervals equal to the divisions of the scale employed. Thus at the scale of 4 inches to a mile, if we make those intervals alternately equal to the $\frac{1}{4}$ and the $\frac{1}{8}$ of an inch, they will represent 110 and 55 yards, and serve in filling in the details.

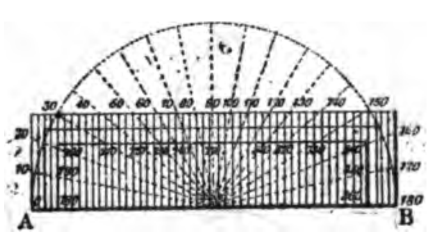
(75.) The protractor consists of a semicircle of thin transparent horn. Its circumference is subdivided into degrees and half degrees, and its graduations on the outer arc extend from right to left from 0° to 180°, whilst on the inner arc, corresponding to the rest of the circumference, the graduations from right to left run from 180° to 360°. The margin A B is parallel to the diameter 0—180.

FIG. 65.



There is another kind of protractor, formed of a rectangular piece of ivory, divided and graduated from left to right, as in this diagram, the margin A B coinciding with the diameter 0—180. Its surface is covered with a series of parallel lines perpendicular to the margin.

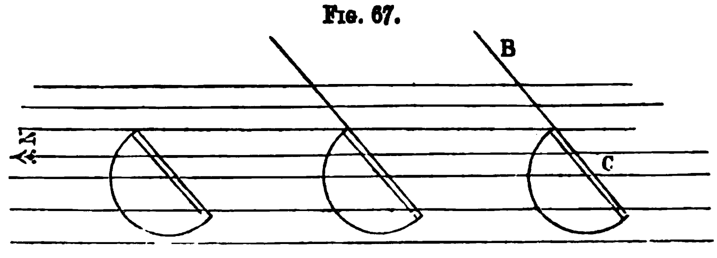
FIG. 66.



In protracting the bearings it should be carefully borne in mind that they are counted from north to east, south and west.

If we want, for instance, to protract a bearing of 50° taken at C, place radius 50° of the horn protractor on one of the parallel lines, and slide it along until the margin passes through C, then draw C B.

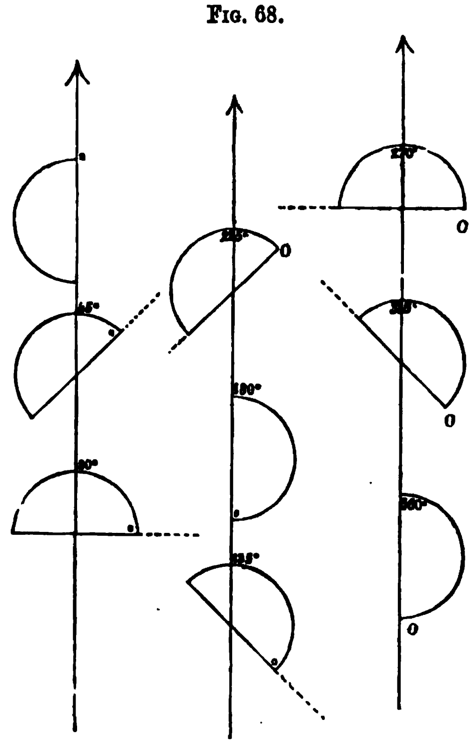
FIG. 67.



From 0 to 180°, the graduations of the outer circle serve to protract, but from 180° to 360° we have recourse to the inner circle.

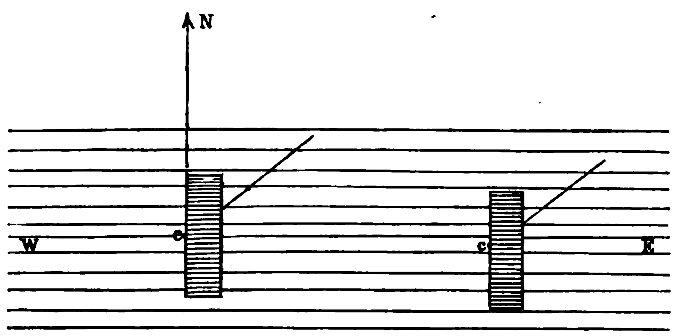
When employing an ivory rectangular protractor, these parallel lines will represent perpendiculars to the magnetic meridian, and correspond to those that are drawn across the instrument. To protract with it a

FIG. 68.



bearing of 60°, for instance, through c, place the centre of the protractor at c, and make any one of the lines across it coincide with one of those drawn on the paper, without moving the centre from c. The

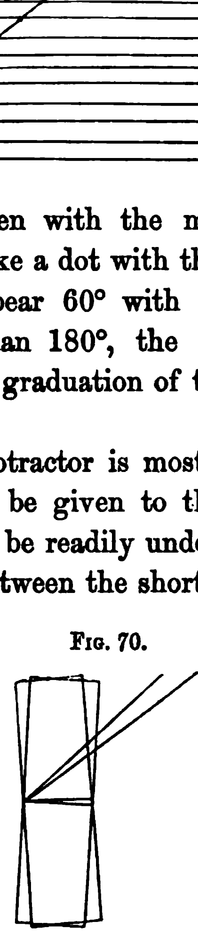
FIG. 69.



margin A B coincides then with the magnetic meridian. At the extremity of radius 60° make a dot with the pencil, and the line drawn from c to that dot will bear 60° with the magnetic meridian. If the bearing is greater than 180°, the protractor is placed to the left of the point c, and the graduation of the inner circle serves to protract the angle as before.

Although the ivory protractor is most generally employed in this country, preference should be given to the horn one, as giving more exactitude: it will, in fact, be readily understood that the slightest deviation from coincidence between the short line across the ivory instru-

FIG. 70.

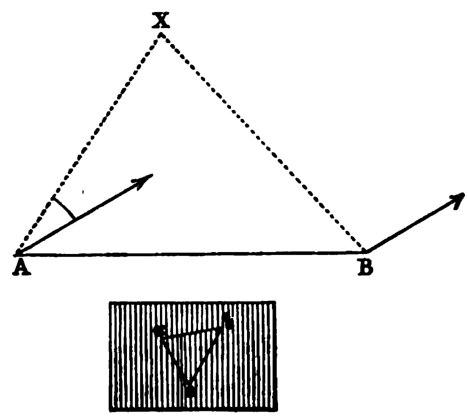


ment and that of the plan, will, owing to that shortness, much affect the true position of the margin. The same deviation with the horn instrument, whose radii are all equal, will not produce so great an inexactitude.

The following problems will familiarize with the use of the prismatic compass :—

(76.) 1st. *To find the projection of a point, X, knowing those, a, b, of two given points, A and B.*

FIG. 71.



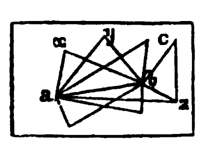
Station at A, take the bearing of A X; repair to B, take the bearing of B X; protract those angles through a and b, the projection x is found.

This problem enables us to fix on the plan the station we occupy on the ground we survey.

If A and B are inaccessible and X accessible, station at this point, take the bearings of X A and X B, protract them through a and b as before, and produce a x and b x till they meet in x.

This method of intersection is very expeditious, since several azimuths can be obtained at the same station (Fig. 72). The angles

FIG. 72.



z, y, x, &c., should not be too acute (44), and when we find them to be so, we must verify the position of those points by taking a third bearing from another station, from c, for instance.

(77.) 2nd. *To survey a road A B C D.*

Station at A, take the bearing of B, protract it through a: measure A B and carry it on a b at the scale. At B take the bearing of C and protract it (Fig. 73), measure B C, draw it on b c, and so on. This method, known under the name of *traversing*, can be simplified by omitting every other station, B, D, &c. Having taken and protracted the bearing of B, we measure A B, and without stationing at B we go

FIG. 73.

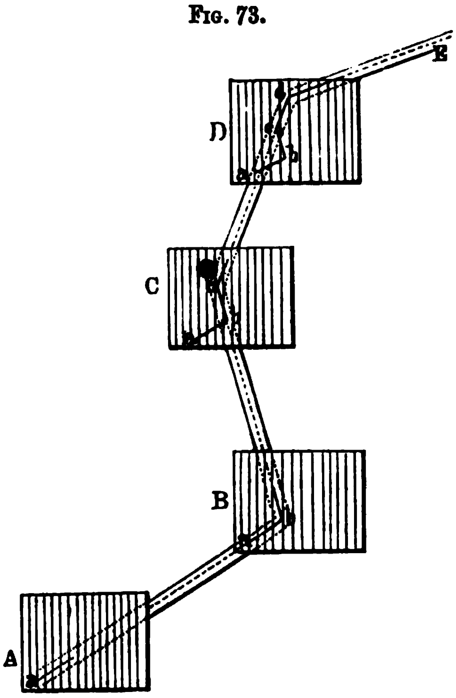
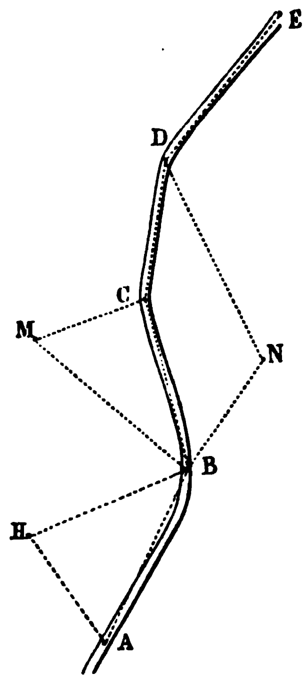


FIG. 74.



on and measure B C. Arrived at C, we mark the distance a b at the scale, and take the bearings C B and C D, which we protract, and having carried distance B C on b c, we start afresh. This expeditious process is called taking the back angle.

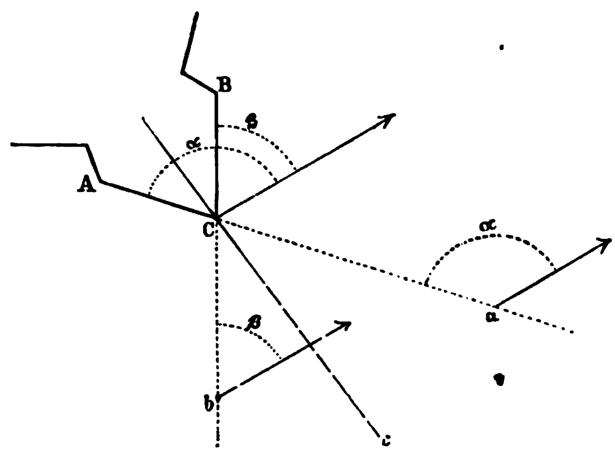
If some points of importance, H, M, N (Fig. 74), lie on either side of the road, their bearings, taken from A, B, C, D, enable us to determine their projections on the plan.

3rd. *To trace the direction of the capital of a bastion or of an inaccessible work.* (Fig. 75.)

Mark two points, *a*, *b*, on the direction of the prolongation of the

faces; take the azimuth α of $a\ A$, that β of $b\ B$, and their difference $\alpha-\beta$=angle $A\ C\ B$, and $\frac{\alpha-\beta}{2}$ is the angle formed by the capital and either face.

FIG. 75.



(78.) This instrument is preferable to the plane table in mountainous or woody countries where several points cannot be seen from a same station. *It is the best instrument for military purposes.*

In using the instrument, it is advisable to place it on a stand, because while holding it in the hand the slightest motion of the body precludes accurate reading, and also because it becomes easier to place the sight vertical, a most important condition, inasmuch as its obliquity may cause errors of even 10 degrees in the azimuth of an object much above the horizon. We should also carefully avoid the vicinity of any steel scabbard, sword, bayonet, and even carry no knife or key in our pocket, for they would affect the direction of the needle.

(79.) The magnetic and terrestrial meridians do not coincide; the angle they form at a given point is called the declination or variation. It can be found by tracing a terrestrian meridian and comparing its direction with that of the needle. Conversedly, by means of the declination, the true meridian can be obtained.

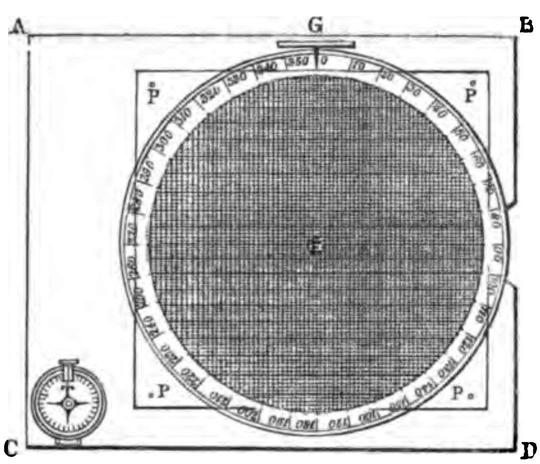
This declination varies in different parts of the globe; but a prismatic compass constructed for England may be employed anywhere, since the angles it determines, being the difference of two azimuths, are

not altered where both bearings are simultaneously larger or less by the same quantity. The survey will therefore proceed equally well; but we shall require the declination to trace the direction of the true meridian.

The variation, for the same locality, is subject to periodical changes; thus, in 1580, it was 11° 30′ east at Paris; it was 0 in 1663, and 19° 26′ west in 1861. Besides those local and periodical changes in the declination, the needle presents diurnal variations which may amount to as much as 25 minutes: they will of course affect more or less the exactitude of the survey; but as the prismatic compass serves only to fill in the details in regular surveys, the error can be neglected.

(80.) A French officer, M. Trinquier, has lately invented an instrument, *echelle-rapporteur*, which is admirably suited for field purposes, inasmuch as it permits to protract bearings and lay down distances without protractor rule, scale, or compasses. The principle is so simple that one may be constructed in a few minutes. It consists of a board,

Fig. 76.



A B C D, on the middle of which is fixed a circle of thin pasteboard movable in every direction round its centre, E. Its circumference is divided into 360°, and its surface is ruled over by two systems of parallel lines at right angles to one another.

The lines parallel to diameter 90°—270° are red, and are at intervals more or less great, according to the scale of the intended sketch, each interval representing 10, 20, &c. paces. Every fifth line is made

thicker to facilitate the reading. The other set of parallels is black, and the lines are at any interval deemed convenient.

An index is invariably fixed on the board at G; it touches the graduated circle, but does not prevent it from turning. The diameter G E will represent the magnetic meridian.

The paper on which the sketch is to be made must be thin or transparent; it is stretched over the board, and is kept in its place by four drawing-pins, p, p, p, p. The board is cut out on one side to allow the fingers to turn the circle.

To trace a direction, the bearing of which is found to be, say 130°, we turn the circle until graduation 130° comes under the index G: it is clear that all the black lines are now parallel to the direction required, and this is at once traced by following with a pencil the black line seen through the paper. The distance measured in that direction—say 150 paces, is laid down by marking over the black line across 15 intervals of the red lines.

The instrument may be made still more handy in fixing the prismatic compass in a corner of the board by means of two brass screws.

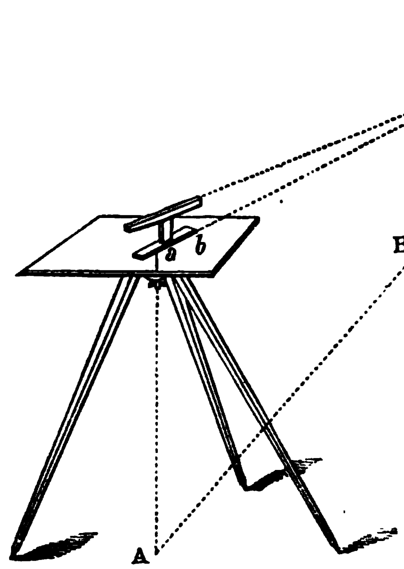
CHAPTER VI.

PLANE TABLE.

(81.) The *plane table* is employed to draw the angles at the same time they are observed, instead of measuring them and protracting them afterwards.

In its most complete state it consists of a square board of wood about a foot or eighteen inches square, mounted on a tripod stand; it can move freely on that tripod, and be placed in any position in which a clamp screw permits to fix it. The paper is stretched and fixed

FIG. 77.



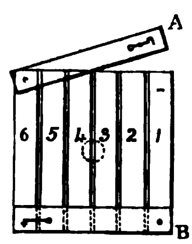
upon this board. The angles are observed by means of a brass rule supporting a telescope movable in a vertical plane round the point of support.

This instrument was hitherto much complicated by a quantity of

contrivances destined to render it more perfect, but in reality adding to the causes of error; it is at present very seldom employed in this country by civil engineers, or officers. For military purposes, however, it is unquestionably a most valuable instrument, which saves both time and trouble; and its construction can be so simplified as to enable almost everyone to attempt it.

The staff officer in France frequently carries his plane table in his holsters: it is formed of 6 thin rules, about 2 inches wide and 1 foot long, pasted on a piece of linen or kid, on which the paper is fixed. These rules are parallel and a little apart, so as to be easily folded flat together. Two other rules, A and B, maintain them open and give

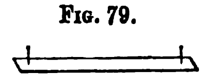
FIG. 78.



strength to the whole; they turn on a pivot at one end, and a hook at their other extremity catches a ring screwed to the splits 1 and 6. A movable socket under the rules 3 and 4 permits to fix this table on a stick when it is required for use. After work, the stick is removed, the socket unscrewed, the hooks unfastened, the rules A and B turned round their pivot till they coincide with splits 1 and 6, and the various pieces folded alternately one upon another. (See 90.)

The telescope, or sight ruler, is replaced by a wooden ruler with two needles fixed in an upright position.

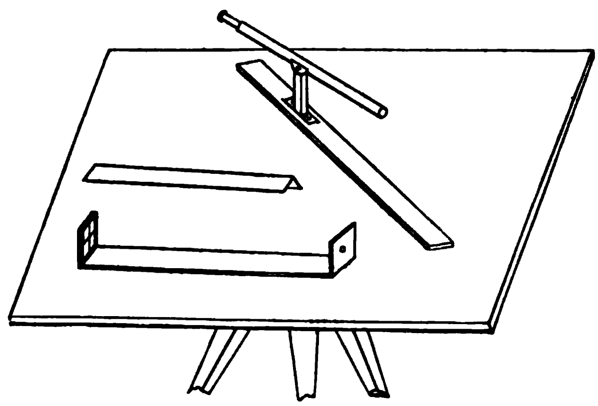
FIG. 79.



A plane table may also be formed with a piece of pasteboard provided with a socket of strong paper, into which a stick may be inserted for support. The sight, reduced to its most simple form, will be the edge of a piece of paper folded longitudinally.

The sketch book on the left arm might even be a substitute for the table.

FIG. 80.

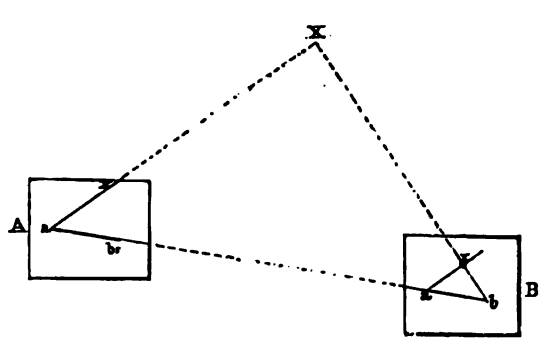


(82.) Whatever the form of a plane table may be, we use it for fixing on the minute the projection of the vertex of a triangle, a side of which is given, or two vertices of a quadrilateral figure knowing the other two, or the fourth vertex knowing the other three. In all these problems, the angles are traced instead of being measured.

(83.) 1st. *To fix on the plan the projection of a point, X, having already those, a, b, of two accessible points, A and B.*

Station at A placing the table as level as possible by moving its

FIG. 81.



legs; place the sight ruler on a b, and turn the table till the point B is seen in a line with the edge of the ruler; then the line a b has been placed in a same vertical plane with A B, and the table is clamped firm

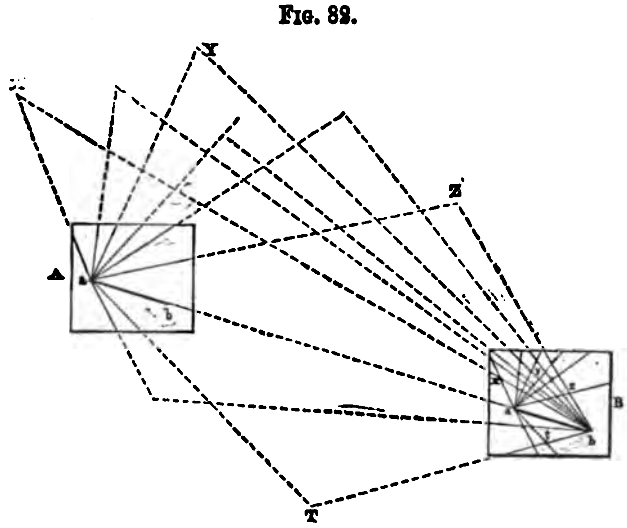
in that position. Keeping the edge of the ruler on the point a, turn it till it is in a line with X and draw a x.

Repair to station B and repeat the same operations: place the ruler along a b, turn the table till A be in a line with it; clamp the screw, turn the ruler round b till x be in a line with it, and draw b x.

The intersection of a x and b x determines the projection x of the point X and the angles B A X, A B X have been traced and at once reduced to the horizon.

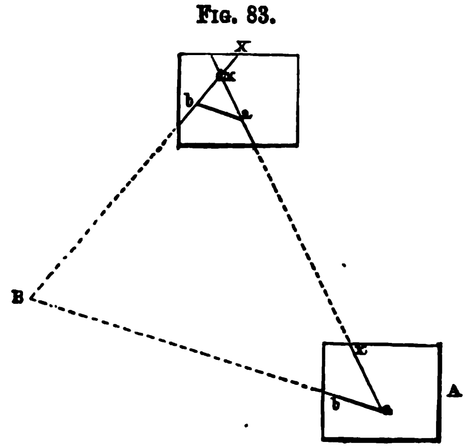
In an open country several points, x, y, z, t, may thus be determined by one station only at each extremity of the given line, A B. (Fig. 82.)

Fig. 82.



(84.) 2nd. *One of the two given points, B, is inaccessible.*

Fig. 83.

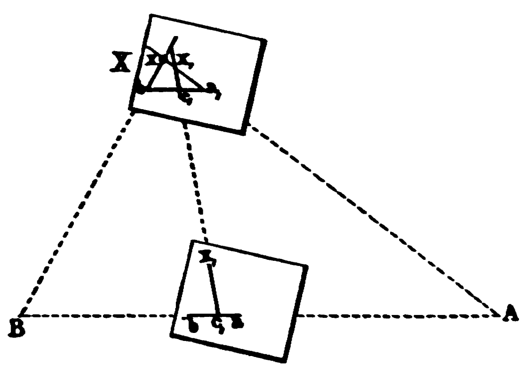


Station at A, and draw a x as above. Station at X, place the ruler along a x, turn the table and clamp it as soon as A is in line; place the ruler's edge on b, and turn it round till B is seen, trace a b, which *intersects* a x, at the required point x.

(85.) 3rd. *The two given points are inaccessible, but a station can be made between them.*

Station at a point C situated on direction A B, and on the plan

FIG. 84.



(Fig. 84) mark in c, its *supposed* projection. Place the ruler on a b, and turn the table till A (or B) be in line, and clamp it. Place the ruler on c, and make it move round it till X be in line, and draw c,x, giving angle x,c,b=X C B; plant a staff or leave a man on C.

Repair to X, place the ruler on x,c, turn the table till C be in line, and clamp it; put the ruler on b and move it round till B is in line, and draw b x; put the ruler on a and turn it till A is in line, draw a x, which intersects b x at the required point.

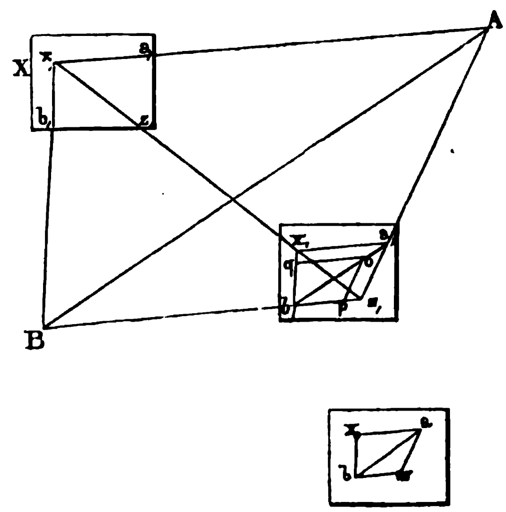
(86.) 4th. *To fix the projections of two accessible points, X and Z, by means of two inaccessible given points, A a, B b.* (Fig. 85.)

On a corner of the minute, or on a piece of paper provisionally stuck on it, draw a line x,z, which we suppose to represent X Z. Station at X, and place x,z, in the same vertical plan with X Z (84), and clamp the table: put the ruler on X, and turn it till A is seen in line, and draw x,a,; turn again till B is in line, and draw x,b,. Repair to Z, and by a similar operation draw x,a,, z,b,.

A quadrilateral figure, x,z,a,b, is thus formed, similar to A B X Z.

To fix it at the scale on the minute, on a,b,, take b,o=a b, and draw o p parallel to a,z,, and o q parallel to z,x,; the figure b, o p q represents the quadrilateral figure A B X Z at the scale. It is then easy to draw it on a b: from a as centre with radii o p, o q describe two

FIG. 85.



circumferences; from b as centre with radii b,p, b,q, describe two other circumferences, which shall meet the former in x and z, the required projections.

To draw through a given point a line parallel to a given line, place the sight ruler on the line and look for some object 200 or 300 yards distant in that direction: move the ruler to the given point and turn it round till the same object be in line the edge of the rule will be parallel, or very nearly so, to the given line.

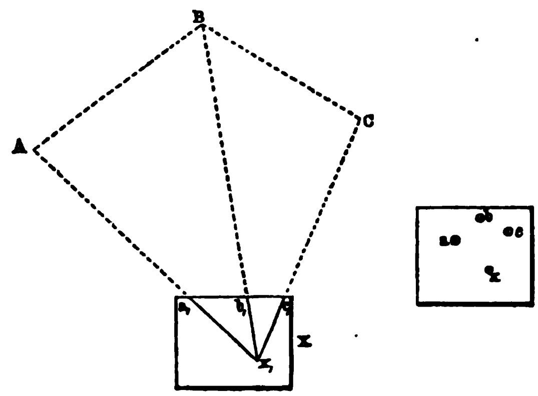
The parallels o p, o q, are usually drawn in that manner.

5th. *Three inaccessible points, A, B, C (a, b, c), being given, to determine the projection of a fourth point, X, accessible.*

The point X is at the same time on the segment of circle described on A B and containing the angle A X B, and on the segment containing angle B X C described on B C. If, therefore, we station at (Fig. 86) X, and construct the angles A X B and B X C, which is easily done by assuming any point, x, for vertex on an auxiliary piece of paper, and aiming with the ruler successively at a, b, and c, and tracing X A,

x_1b_1, x_1c_1, the projection X will be determined on the plan by describing

FIG. 86.



on a b a segment that contains angle $a_1\ x_1\ b_1$, and on b c a segment containing angle $b_1\ x_1\ c_1$.

This process is not very practical. Among several other methods the best consists in fixing on a corner of the table a piece of tracing-paper. Taking on it any point, x, at random we draw as above the lines $x_1\ a_1$, $x_1\ b_1$, $x_1\ c_1$, making the angles A X B, B X C.

Unfastening the tracing-paper, we move it on the minute till these three lines pass respectively through a, b, c, and then we prick x, and obtain the required projection.

This problem enables us to find our place, x, in a survey by means of three given points.

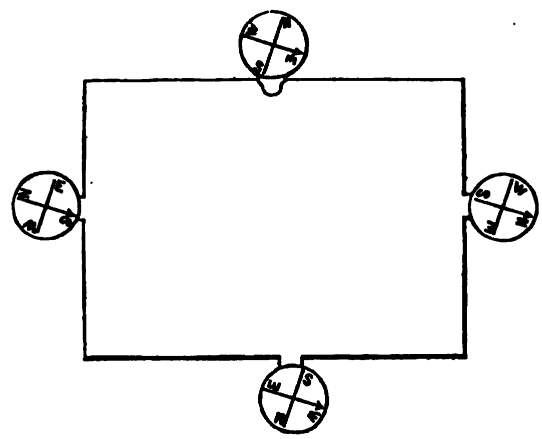
The plane table is an excellent instrument in even and open ground, where a canvas is rapidly constructed; and those officers who have once employed it will always prefer it to any other; nevertheless, it should be rejected in mountainous or woody countries, where several points can seldom be seen from the same station.

(89.) A magnetic needle or compass may be advantageously added to the plane table for the purpose of facilitating the finding of a station. When the projection a b of a line, A B, has been placed in the same vertical plane with A B (84), read the angle marked by the needle, and whenever it is required to place the table in a position parallel to this, it is done by turning it till the compass gives the same reading.

By means of this addition the plane table permits to operate with

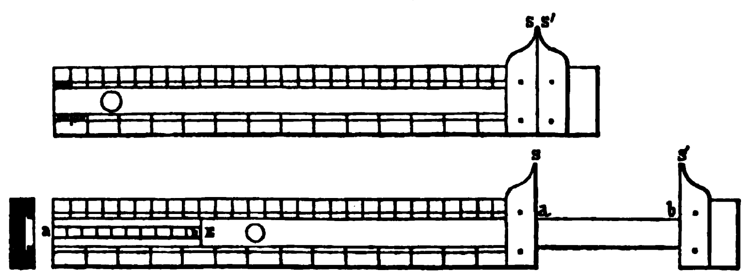
S, for instance, is brought under the point of the needle. The compass being afterwards moved to one of the adjacent sides of the table, the needle will point to W, N, or E, as the case may be, thereby avoiding the necessity of adding 90° to the azimuth whenever the compass changes side.

FIG. 90.



(91.) Major Fèvre combines the scale and compasses into one instrument. It consists of two rules of equal length, the wider one carrying any

FIG. 91.



two scales, say four inches and two inches to the mile. These two rules can slide upon one another, so that at both extremities the distances, a b, are equal. Two steel points, s s, fixed at the end of each ruler, will thus enable us to measure or carry a distance, the reading of which is found at the extremity, E, of the small rule. A scale of paces may also be made on the bottom of the groove of the wider rule.

This plane table working excellently in the field, is now superseding all others.

CHAPTER VII.

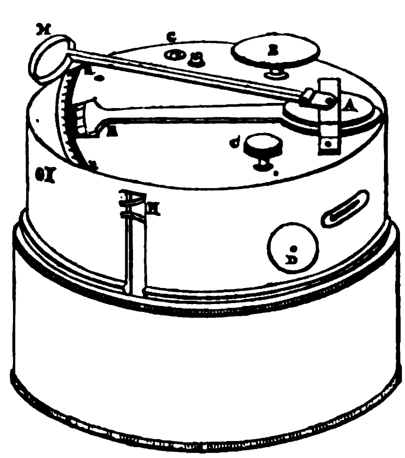
SEXTANT AND CROSS-STAFF.

(92.) The *box sextant* is employed to measure the angle between two objects. It consists of a cylindrical box containing an index-mirror, under A, to which is attached on the upper surface or plane of the sextant an index-arm, E. Both this mirror and the index are movable by means of a screw, B. The index-arm is terminated by a vernier wherewith we read the graduations of the limb, m n, within a minute (95). The graduation extends from 0° to 120°; and a magnifying glass, M, facilitates the reading.

The sight D, to which a telescope may be adjusted if required, is opposite to another mirror (under G), called the horizon-glass, that has half its surface silvered.

Both mirrors are fixed, by the maker, perpendicularly to the

FIG. 92.



plane of the sextant. By means of two levers in H the observer interposes two dark glasses between the mirrors and an object too brilliant to be easily seen, and the eye-piece of the telescope is also

provided with a dark glass for the same purpose. It is often recommended to adjust this instrument before employing it, but we should advise officers to meddle as little as possible with adjustments: if the sextant is put out of order, it is better to send it to the optician; yet, as accidents will happen in the field, and opticians are not always at hand, here is an account of the process.

(93.) To be in perfect adjustment, both the index-mirror and the horizon-glass should be perpendicular to the plane of the sextant, and both parallel when the vernier is at 0.

Through the process of construction of the maker, the index-mirror is supposed to be right, therefore we have only to ascertain the perpendicularity of the horizon-glass. To do so, hold the sextant horizontally and look through the sight D, at the distant horizon or at the sun. If two images appear, unscrew the key C, and putting it to the key-hole G, turn it till the two horizons or the two suns coincide. The glass is then right.

To verify the parallelism, place the index exactly at 0, and, holding the instrument horizontal, look to the angle of a house far distant or to the lower limb of the sun—so placing the eye as to see directly through the hole of the slide and the unsilvered part of the horizon-glass. The direct image and that reflected by the index-mirror to the horizon-glass should appear as one: if not, fit the key C to the key-hole I, and turn till both images coincide. The instrument is then adjusted.

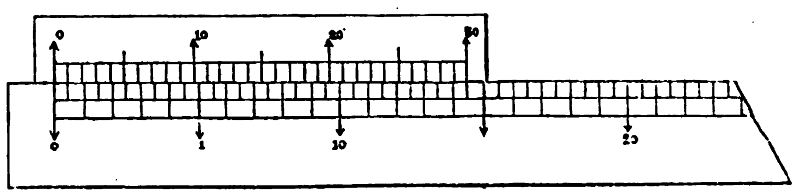
(94.) To measure the angle between two objects, set the vernier at 0°, hold the instrument with the left hand in the plane of the objects, look through the slide D or the telescope at the left-hand object, and with the right hand turn the screw A until the reflected image of the right-hand object coincides with the direct image of the left. The vernier marks then the angle required.

To obtain the angle subtended by two objects situated in the same vertical plane, set the vernier at 0, hold the instrument vertically in the right hand, and bring the reflected image of the upper object to coincidence with the direct image of the lower one. The vernier marks then the required angle.

(95.) The *vernier* is a contrivance applied to an instrument employed for the measurement of angles or distances, so that the fraction of the

smallest division of a graduated limb or scale may be read. It consists of a little arc or rule according as the graduated scale is a circumference or a straight line.

FIG. 93.



Let us take on the limb and on the vernier two equal lengths or arcs, the first containing n—1 divisions equal to D, the second n divisions equal to d. These lengths will therefore be represented by (n−1) D and n d, and as they are equal (n−1), D=n d, hence $D-d=\frac{D}{n}$. It follows from this that when the 0 of the vernier has passed a division of the limb, this 0 is in advance upon it of $\frac{D}{n}$, $\frac{2\,D}{n}$, $\frac{3\,D}{n}$, &c., according as the first, second, third, &c., of its own divisions coincides with one of the limb's divisions. Hence, when measuring distances or angles with an instrument provided with a vernier, we must ascertain which division of the vernier coincides, multiply it by $\frac{D}{n}$, and add this product to the last division of the limb over which the 0 of the vernier has passed. In the box sextant the value of D=30 minutes, and n=30, therefore D−d=1′. The limb is divided in half-degrees, and 30 divisions of the vernier correspond to 29 of the limb. If the 0 of the vernier (marked with an arrow) has passed the 12th degree of the limb, for instance, and if its 9th division coincides, the angle measured is 12°−9′. If the arrow has passed 43° 30′ and the 23rd division of the vernier coincides, the angle =43° 53′.

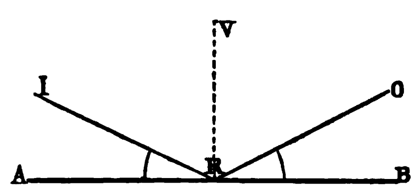
(96.) The box sextant *seems* preferable to the compass when accuracy of measure is requisite, since it can, even without employing a stand, give an angle accurately within one minute, and measure the angles of elevation and depression besides. It has, however, the drawback of

furnishing us with the actual angle instead of its horizontal projection, and a complete series of angles round a station may considerably exceed or fall short of 360°. The error due to this cause exceeds that of the prismatic compass used with a stand, and the exactitude of measurement is, after all, but apparent, therefore the sextant cannot be preferred to the compass.

There is a mode of reducing angles to the horizon, but it is tedious, and should be avoided: a little practice will enable the observer to do it himself by selecting a point exactly vertical above or below the objects, in the plane of the true horizon.

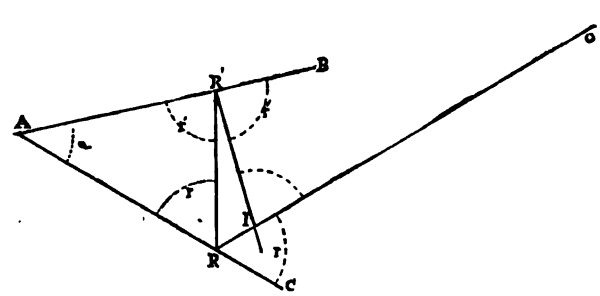
(97.) In order to understand upon what principle the sextant is constructed, let it be observed that if a ray of light, O R, falls obliquely upon a mirror, A B, it is reflected in a direction, R I, making with

FIG. 94.



the perpendicular, V R, the angle of reflection, I R V, equal to the angle of incidence, O R V. Now, when two mirrors, A B, A C, form between themselves an angle, a, if a ray of light, O R, falls

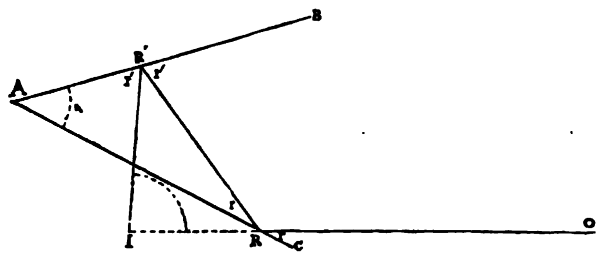
FIG. 95.



upon one of them, A C, to be reflected to the other, A B, in R R', and there again reflected in the direction R' I, the angle formed by the direct ray, O I, and its reflected image, R' I, is double the angle a. This is seen at once on the figure: Angle R' I O = R R' I

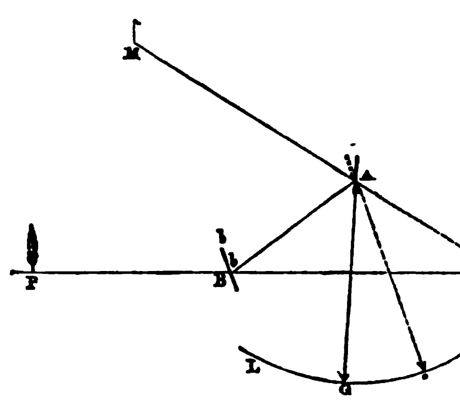
$+R'\ R\ I = 180 - 2\ r' + 180 - 2\ r = 360 - 2\ (r + r')$. But in triangle A R R', $a = 180 - (r + r)$, therefore $R'\ I\ O = 2\ a$.

FIG. 96.



Let A be a mirror (Fig. 97), B another one with half its surface silvered, and M P two objects subtending an angle, M E P. The image of M is reflected from A to B, and from B to E, and the angle

FIG. 97.



A E B is, according to what has just been said, equal to twice the angle o A G of the mirrors. Now, if P is in a line with E B, the angle A E B is precisely the angle required.

In the box sextant the mirror A constitutes the index-mirror, and B the horizon-glass. As the latter is unsilvered in b b, the object P is perceived directly along E P; therefore, if the mirror A is turned until the reflected image of M coincides with P, the two mirrors will then make an angle equal to half that subtended by the objects. In the box sextant, the index-arm A G, fixed to mirror A, points to the graduation of the limb L O, which is numbered double, so as to give

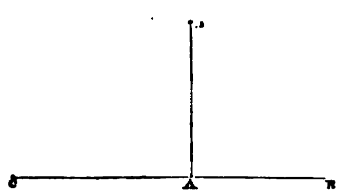
the real angle at once. When the movable mirror, A, is parallel to B, the index points to o.

(98.) The problems which we have investigated with the plane table and the prismatic compass can be solved by means of the sextant, by measuring and protracting the angles instead of tracing them, as with the table, and plotting them by differences of azimuths, as with a compass. We shall not, therefore, repeat their solution, as the student, having once understood how to handle the sextant, can easily find it. One application or two, however, may be given.

1st. *Through a given point,* A, *to trace on the ground a line perpendicular to a given line,* B C.

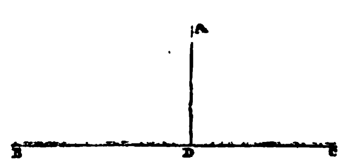
If A is without B C, plant a staff at it, set the vernier at 90°, and marching from C to B, look through the slide towards B till

FIG. 98.



the reflected image of the staff coincides with B. The point D, at which the coincidence takes place, determines A D, at right angles with B C. If A is on B C, set the vernier at 90°, and send a man with a staff to the right, while you stand at A and look through the

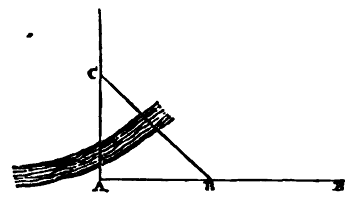
FIG. 99.



slide at C (Fig. 99). As soon as the reflected image of the man coincides with C stop him, and the point D, which he then occupies, determines A D perpendicular to B C. When the man is sent on the left the sextant must be inverted.

2nd. *To find the distance between* A *accessible and* C *inaccessible.*

FIG. 100.

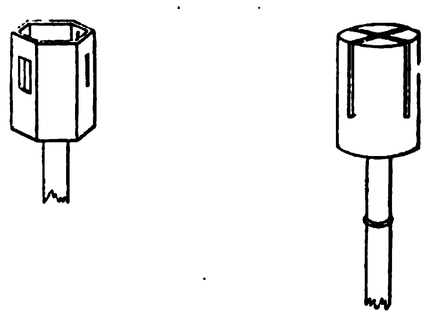


Set the vernier at 90°, and through A trace a perpendicular, A B to C A, as explained; then set the vernier at 45°, and marching in direction B A, and aiming at A, move backwards or forwards until the reflected image of C coincides with A. The point B, at which it happens, gives us the isosceles triangle C A B, and B A=A C.

(99.) By means of the *cross-staff*, an instrument very familiar to Civil surveyors, perpendiculars on the ground are traced; it can advantageously be employed in military surveys to fill in the details.

It has various forms. The most general consist of a cylinder or a

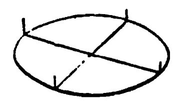
FIGS. 101 and 102



prism of brass, having four longitudinal grooves, cut through so as to give two directions, at right angles.

It is sometimes formed of a circle of brass with two diameters at right angles bearing a sight at each extremity.

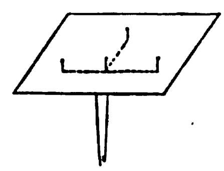
FIG. 103.



In whatever form, it is fixed upon a stand so pointed at its extremity as to be easily driven and steadied into the ground.

As it very seldom happens that this instrument is to be found in the field, it can easily be replaced by a small board nailed to a stick. Four needles or pins planted at right angles, as in the diagram, will

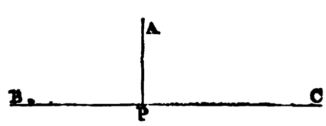
FIG. 104.



answer the same purpose as the grooves. This instrument will be found very handy in mountainous and woody districts, ravines and marshes; and when measures are taken by pacing, the details of a survey may be rapidly filled in by its assistance, as may be seen by the following few exercises.

(100.) 1st. *Through a given point,* A, *to trace a perpendicular to a given line,* B C.

FIG. 105.

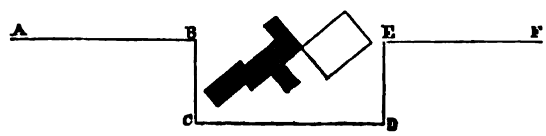


March along B C, carrying the instrument with the left hand, and aiming along that direction through a groove, and see through the other if you can perceive the point A, if not, march on. After a few trials the point A will be seen; then the point P, from which A is seen through the second groove, gives the extremity of the perpendicular required.

(101.) 2nd. *To produce a line beyond an obstacle.*

Let A B be the line; at B trace B C, perpendicular to A B, which

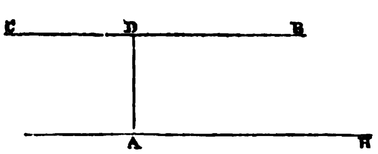
FIG. 106.



is done by looking through a groove along B A, and sending a marker to plant a pole in the exact direction of the rectangular groove; measure B C, trace C D perpendicular to B C, and produce it till the obstacle is passed; trace D E perpendicular to D C, making it equal to C B; then E F traced at right angle with E D will be in the prolongation of A B.

(102.) 3rd. *Through a given point,* A, *to draw a line parallel to a given line,* B C.

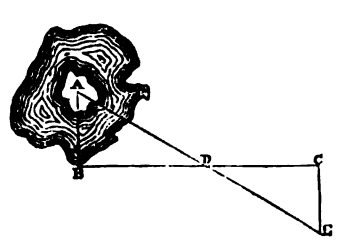
FIG. 107.



Find on C B the foot of the perpendicular A D. Place the cross-staff in A, one sight directed on A D, the other will be directed on A H parallel to B C.

(103.) 4th. *To find the distance between two points,* A, B, *one of which,* A, *is inaccessible.*

FIG. 108.

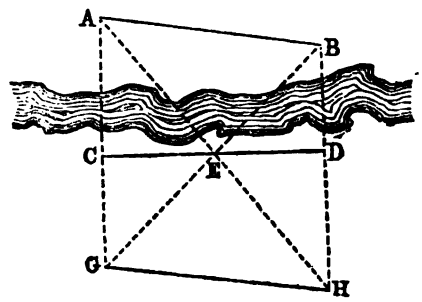


In B trace a line, B C, perpendicular to B A, and mark its middle, D; at C trace C E at right angle with C B, and march along it till

arrived in E you perceive D and A in a line, the length C E measures then A B.

(104.) 5th. *To find the distance between two inaccessible points, A and* B.

FIG. 109.



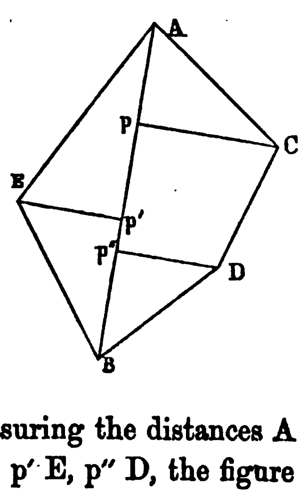
Trace any direction, C D, and mark on it the extremities C and D of the perpendiculars A C, B D, respectively drawn from A and B to that line; produce them on C G, D H. Bisect C D in E. March along D H till you see E and A in the same direction, and mark the point H from which you perceive the coincidence.

Do the same operation on C G, till in G you see E and B coinciding in direction. The line G H measures A B.

(105.) 6th. *To survey a polygon,* A B C D E.

Trace the diagonal A B: find in it the feet of the perpendiculars

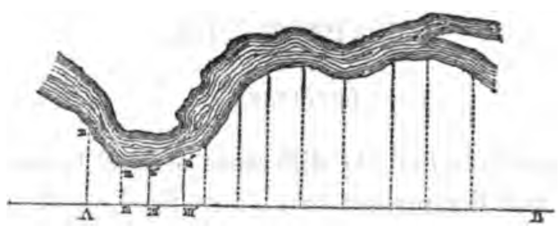
FIG. 110.



p C, p′ E, p″ D. Measuring the distances A p, p p′, p′ p″, p″ B, and the perpendiculars p C, p′ E, p″ D, the figure can at once be drawn.

The sinuosities of a river, a wood, a piece of water, &c., can be obtained with great exactitude by this process:—Advancing along a

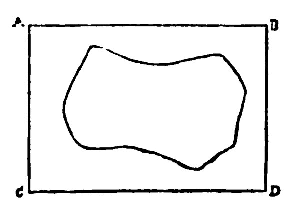
FIG. 111.



line, A B, measuring successively the distances A m, m m′, &c., and their perpendicular offsets, An, mm, m′n, &c.

(106.) The area of a field can also be found with the help of a cross-staff. To do this, trace a rectangle, A B C D, that encloses the field.

FIG. 112.



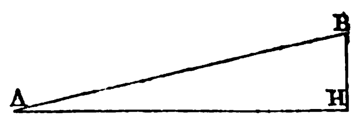
field. Draw it at the scale on a piece of thick paper; march along the sides of the rectangle, taking the offsets as before described, and draw the borders of the field. Calculate the area of the rectangle: cut it and weigh it: cut out the field and weigh it. Its area has to that of the rectangle the same proportion as is given by the weights.

CHAPTER VIII.

LEVELLING.

(107.) To level is to find the difference of level between two or more points. Let A and B represent two points fixed on the plan by one of the foregoing methods. In the triangle A B H, the angle H is right,

FIG. 113.



the projection A H is known by measuring it at the scale; therefore, if we could observe the angle of elevation B A H, we could obtain the altitude B H by either calculating or constructing the triangle A B H.

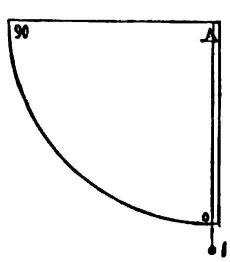
Again, if H B was directly or indirectly measured the problem would be solved.

The instruments of levelling are of two kinds: some give us the angle of elevation or of depression, others the height itself.

The only instruments that can be recommended to an officer for the purpose of observing these angles, are the box sextant already described, and the clinometer.

(108.) The clinometer consists of a quadrant of pasteboard or of

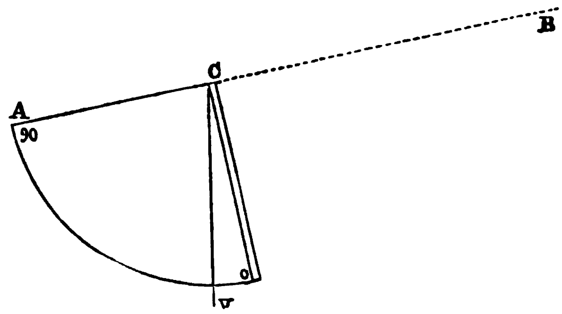
FIG. 114.



brass, having a plummet, A H, suspended at its centre, and graduated as in the diagram on both sides. When we require an angle of eleva-

tion A B H, we look along the edge A C, till B be in sight, when the plummet indicates the angle O C V. For an angle of depression reverse the instrument.

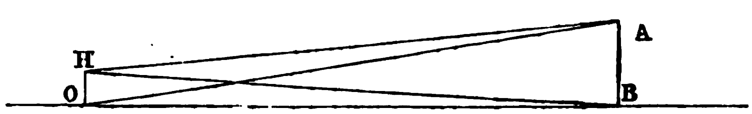
Fig. 115.



The clinometer is quite sufficient for every military purpose, and its extreme simplicity renders it preferable to the box sextant. At all events it makes a capital substitute for it in case of accident.

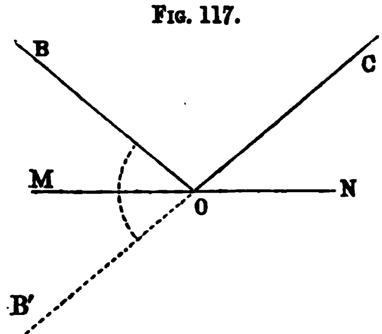
(109.) If a sextant is used (94) in the mode described, the angle A H B which it gives will not differ much from the true angle of

Fig. 116.



elevation A O B when the distance H B is great, and if the operator lies or stoops on the ground this angle will be sufficiently exact.

Fig. 117.

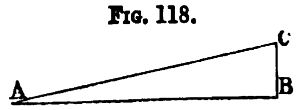


Where a great accuracy is necessary, a reflecting surface should be procured to give a horizontal plane. A hollow vessel, filled with a few inches of water or mercury, will at once procure this artificial horizon;

a looking-glass might also be placed level. Whatever be this auxiliary surface, we measure with the sextant the angle B O B′ formed by an object B, and its reflected image C seen on direction B′. This angle is double the elevation required, since M O B=C O N (97), and C O N= M O B′.

(110.) The distance A B and the angle B A C being known, the height B C can be found by the formula H=B tang *a*, in which B

FIG. 118.



represents the horizontal distance, *a* the angle of elevation and H the altitude.

TABLE SHOWING THE HEIGHT WHEN THE HORIZONTAL DISTANCE A B=100.

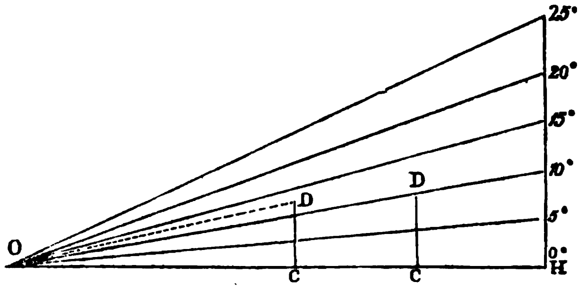
ANGLE.	HEIGHT.	ANGLE.	HEIGHT.	ANGLE.	HEIGHT.
1°	1·74	16°	28·67	31°	60·07
2	3·49	17	30·57	32	62·49
3	5·24	18	32·49	33	64·94
4	6·99	19	34·43	34	67·45
5	8·75	20	36·40	35	70·02
6	10·51	21	38·39	36	72·65
7	12·28	22	40·40	37	75·35
8	14·05	23	42·45	38	78·12
9	15·84	24	44·52	39	80·98
10	17·63	25	46·63	40	83·91
11	19·44	26	48·77	41	86·93
12	21·26	27	50·95	42	90·04
13	23·09	28	53·17	43	93·25
14	24·93	29	55·43	44	96·57
15	26·79	30	57·73	45	100

An example will show how to use this table. The distance between two points is 457 yards—the angle of elevation 10°.

In the column of angles we find that for 10° there is a difference of level of 17·63, when the base is 100 yards; therefore, 100 : 457 : : 17·63 : to the height required=80·55 yards.

If the student is not acquainted with Trigonometry, or if there is no table of tangents to be had, a scale of height may be constructed in the following manner:—O H representing the horizon, draw through O several lines inclined at 5° to one another. If, then, the hori-

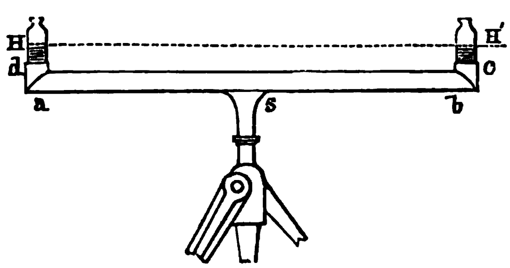
FIG. 119.



zontal distance is carried on O H at the scale—in O C, for instance—the perpendicular erected at C will, by its intersection at D with the line corresponding to the angle of elevation observed, give the altitude C D, the length of which is found by the scale. This altitude is added or subtracted, according, as we have observed an angle of elevation or of depression: the height above the ground of the instrument with which those angles have been measured must also be added or subtracted.

(111.) There are many instruments for levelling; the only one employed to measure directly the altitudes which we shall mention, is

FIG. 120.

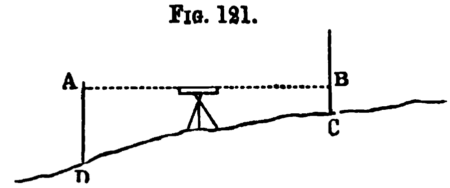


the French water-level, because it is easily constructed. It consists of a hollow tube, a b, of tin or brass about 3 feet long, with two empty cylinders, a d b c, soldered at its extremities, and terminated by two glass bottles. A socket, s, is inserted in a tripod. Its use is to give a horizontal direction: to that effect it is placed level at sight, and water is poured into the tube until it reaches about ⅔ of the height

of the phials. The surface of the water in these bottles determines a horizontal direction, H H′.

To find the difference of level between two points, A and B, station between them: send a man to set a levelling-staff at B; look

FIG. 121.

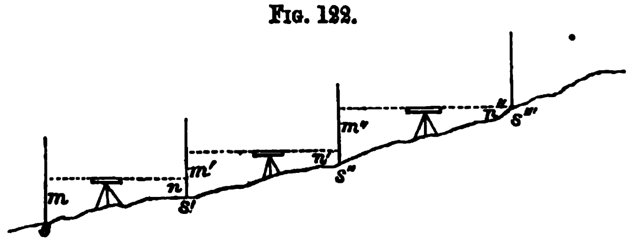


along the surface, H H′, and read the height, B C; send the same or another staff at D, and in the same manner obtain the height, A D. The difference of level is given by A D – B C.

There are several sorts of levelling-staves more or less ingenious, but if none is to be had, a pole divided into feet and inches will answer the purpose. The pole bearer, when in station, will move up and down the pole a piece of white paper, to enable the observer to see more easily its intersection with the artificial horizon. In case the latter should be too far to read the graduation, when sign is made to stop, he will himself read the figure and give it.

When the ground is very uneven, several stations are necessary;

FIG. 122.

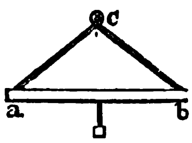


in this case we station between $s\ s'$, $s'\,s''$, &c.; and if m, m', m'' represent the back measures, n, n', n'' the measures in front, the difference of level is found by $(m+m'+m''+ \text{—})-(n+n'+n''+\text{—})$. In this case a field-book will be necessary to write down these observations, whenever the distances are great.

This level is usefully employed to make a profile of the ground on any given direction, an operation occasionally required in the field for projects of fortification. We proceed along this direction, as we have just now explained, assuming any altitude for the point of departure when it is not exactly known.

(112.) A water-level may even fail us: then it can always be replaced by a little ruler, a b, suspended by two strings, c a, c b, having a little weight under it to prevent the wind from shaking it.

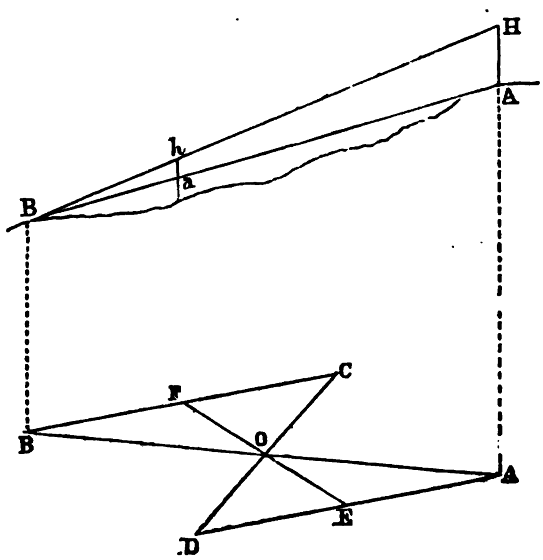
FIG. 123.



When held by the string, the line a b will give a horizontal direction. To make use of it for levelling along A B: Start from A, hold the ruler up to the eye, and aiming along its edge, notice to what point, b, of the ground the visual ray corresponds. Repair there, we shall have ascended a distance=the height of the eye above the ground. Start afresh, from b, and in this manner the number of stations made between A and B, multiplied by the height of the eye above ground, will give the difference of level required.

(113.) The chain may in some instances serve us as a levelling instrument (48), to measure heights, but a clinometer should be preferred. The next example will serve as further illustration. To find

FIG. 124.

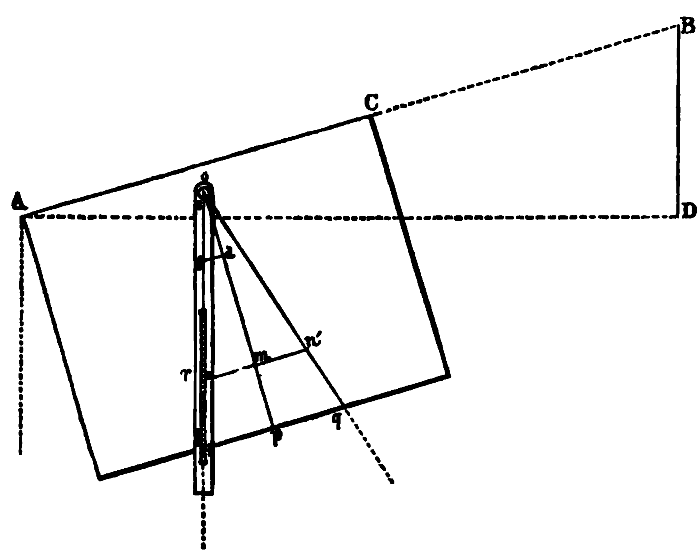


the height, A H, of an inaccessible steeple, A, situated on a slope.

Measure any line, C D, in any convenient spot, bisect it at O, march from D towards A, measuring any length, D E, trace O E, and produce it of an equal length, O F; trace C F, and produce it till it intersects the direction O A, in B. Then O B=O A, and distance, B A, is known.

At any point, a, of A B, plant a pole of such a length, that the eye at B may see its top in line with H. Measure a B and a h, and AH : ah : : AB : aB.

(114.) The difference of level between any two points may be found with the plane table. Referring to the instrument of Major Fèvre (90), we find that a wooden plummet in the shape of a ruler can be suspended in o. Stationing at one of the points, at A, we hold the table in the left hand, and aim along the side, A C, to the second point, B; the plummet remaining vertical, the angles p o q and D A B are equal.



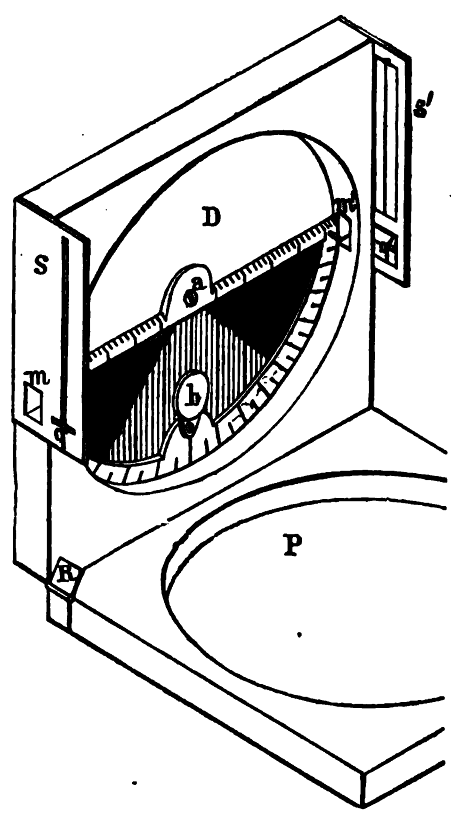
If we carry from o to d, a distance, d o, equal to the projection of A B, the triangle o g d is similar to B A D, and the line g d measures the difference of altitude required. Instead of carrying from o to d the projection of A B, we may carry on o m any multiple, M, of it, and afterwards holding the table in the right hand, the plummet will take a symmetrical position, o q', and the distance, n n', will be

2M times the difference required. The graphical error is thereby diminished.

As, however, it is impossible to reach the point o on account of the screw, the distance o p, which is constant, is marked on s s′ on the edge of the plummet. The multiple of the projection being then measured from s to r, the point m is fixed by taking p m=s′ r. A slit cut through the plummet permits the introduction of the point of a pencil to draw the lines o q, o q′.

(115.) A clinometer has been constructed by Mr. Trinquier to obtain not only the angle of elevation, but also the horizontal and vertical distances between two points. It is contained in the lid of his prismatic compass, P, which is square, and it is kept erect by means of

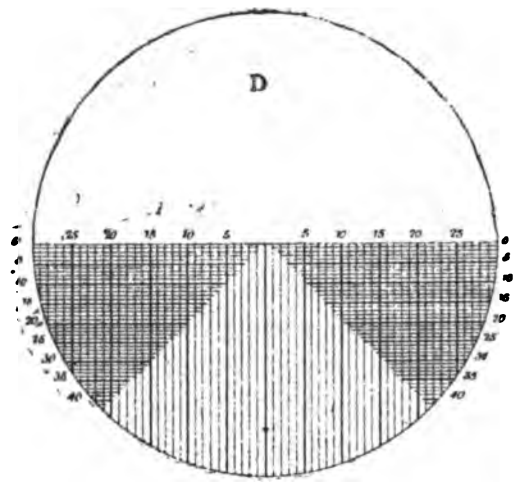
FIG. 125.



a bolt, R. The bottom of this lid, D, is divided into two semicircles by a horizontal line, which we may call the fixed diameter. The lower

semicircle is divided into zones of equal width by vertical lines, numbered from the centre to the right and left. Another series of

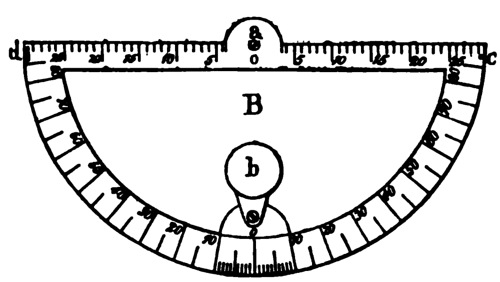
FIG. 126.



lines are drawn parallel to the fixed diameter at half the intervals of the former and are numbered downwards.

A semicircle of brass, B, is suspended by the centre, a, round which it can move freely until we stop it by means of a spring at the back of

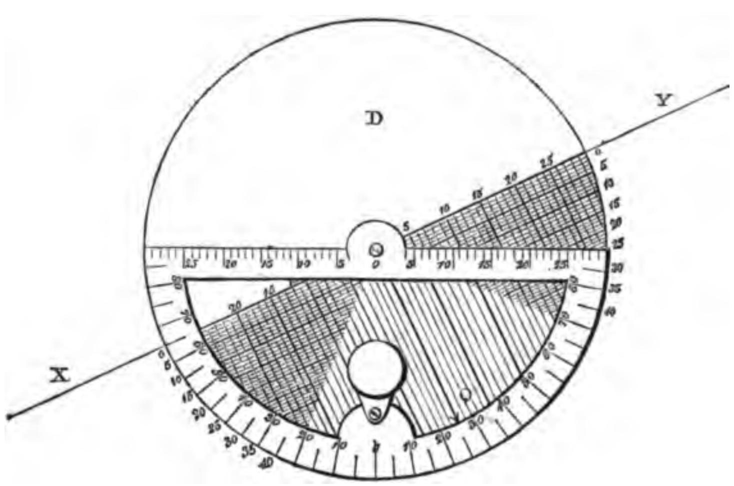
FIG. 127.



the lid. It has the same dimensions as the fixed figure: its edge, c d, bears the same divisions as the fixed diameter, and its circumference is graduated from 0 to 90 on both quadrants. A weight, b, acting as plummet maintains the diameter c d parallel to the horizon in whatever position the instrument is placed. This movable diameter carries two pins in c and d, so that when we see them coincide in looking

through the apertures m, m′, we know that c d is horizontal, and that both the fixed and the movable diameters coincide. Two thin strips of metal, s s′, are screwed to the sides of the lid; one of them, s, is pierced with a vertical and a horizontal slit, the second, s′, carries two hairs to correspond. The vertical slit and hair serve to take azimuths with the compass, and have nothing to do with the clinometer. It is evident that if we apply the eye to the slit q and look at an object until the slit q, the hair q′, and this object be in one line, the fixed diameter will be parallel to this line of sight, whilst the movable diameter remains horizontal. Thus the divisions of the instrument will always form right-angled triangles, similar to those on the ground: the movable diameter or hypotenuse represents the distance between two points, the fixed diameter or base measures the projection of the distance, and the perpendicular shows the vertical distance. An example will at once show how to handle this instrument. Suppose that the line of sight takes the direction X Y, the angle of elevation is at once given at Q. It is here

FIG. 128.



25°. Let now the distance from our station to the object Y be measured along the slope X Y, and let it be 220 yards, for instance. Assuming each division of the horizontal diameter to represent 10 yards, the graduation 22 coincides with the perpendicular 20, showing the projection or horizontal distance to be 200 yards. The vertical distance is read at the extremity of the parallel to the fixed diameter corresponding

to division 22. It is line 18, but as the intervals are only half the vertical ones which represent 10 yards, the difference of level is $18 \times 5 = 90$ yards.

To find the difference of altitude of two points when projections are fixed on the plan, we station at one of them and aim at the other. Suppose that the plan given is a horizontal distance of 190 yards: we find division 19 of the fixed diameter, and see where the movable diameter intersects perpendicular 19. If this point of intersection correspond to horizontal 12, the vertical distance is $12 \times 5 = 60$ yards.

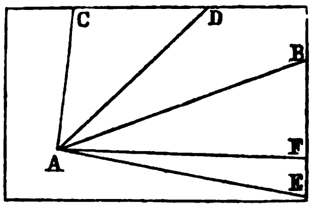
CHAPTER IX.

MILITARY SURVEYING.

(116.) It has already been said that the first step to be made in a military survey is to select and measure a base (43) and by means of angles to construct a canvas connecting the important points of the ground. As the triangles should be of the equilateral form, it is advisable, when time allows, or when the plan is to be made with accuracy, to spend a day over the ground and make a provisional triangulation, indicating approximately the form of the triangles, and thereby enabling us to select the points which will serve to construct the definitive canvas.

This preliminary operation is accomplished as follows: we repair to the extremity, A, of the base we intend selecting, and draw a line on the centre of a piece of paper that will represent the direction, A B, of

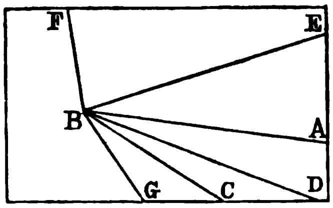
FIG. 129.



this base; having then placed this line on the same vertical plane with its homologous line on the ground as explained before (84), and aiming successively with any ruler (82) at the points C D E F, or guessing (135) at the angles they subtend, we draw the lines A C, A D, A E, A F.

Proceeding to B we repeat this operation on another sheet of paper,

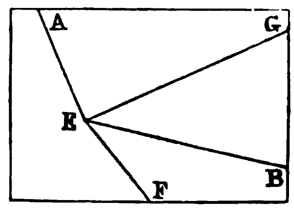
FIG. 130.



aiming at the same points as before, and to others if any are to be seen.

Transporting ourselves to another station, E, &c., we continue to

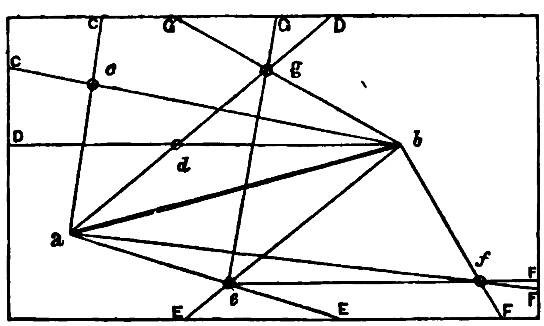
FIG. 131.



protract the angles observed at every station on distinct pieces of paper, until we have been over all the ground which we have to survey.

At home, we assume any length, A B, for that of the base, and transfer round the point A all the angles measured in sheet 1st, which is

FIG. 132.



easily done by placing A on a and A B on direction a b, and pricking with a pin a point on each of the directions A C, A D, A E, A F.

With sheet No. 2, we place B on b, and B A along the direction b a and transfer as explained all the angles observed at B. Several points, c, e, d, f, are thus obtained by intersection, and not to lose them it is usual to surround them with a little circle.

With sheet No. 3 we place E on e, and E A on e a, and continue to transfer the angles. Thus we obtain the relative position of the points of the canvas, and ascertain the form of the triangles.

(117.) The definitive stations being selected from this provisional canvas, we measure the base and draw it at the scale on the minute, and afterwards proceed successively to every station where we accurately observe and protract the angles. According to circumstances the plane table, prismatic compass, or sextant, will be employed for that purpose;

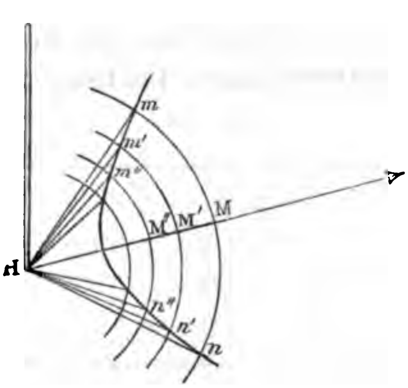
but we readily appreciate the value of the two former. The base, which should be in a central position, is measured either by chaining or pacing. When time is failing we can procure the base from a map of the locality, and the canvas is at once plotted without any preliminary operation. The canvas itself might eventually be procured from a map, but as the points thus found are generally inaccessible, it becomes necessary to determine by means of them the position of accessible stations (18, 76, 88).

The canvas is the most important part of a survey, and we should take the greatest care to make it as exact as the instruments and time at command will permit; it will in the end save much trouble while filling in the details. The objects visible from a long distance, such as steeples, chimneys, remarkable trees, peculiar signals, &c., should be most carefully fixed on the minute, and besides those we should also determine the turnings of high roads, the points of entrance of a road through a wood, a village, &c., and the summits of hills, intersections of valleys, &c.

(118.) When the canvas is completed, it is usual to trace on it the direction of the true north. If the base has been taken from a map ready made, its azimuth is easily found thereon; but if it has been laid down from actual measurement, we trace a meridian on the ground through the extremity of the base or of any line of the canvas, and protract on the plan the angle formed by the two directions.

To trace a meridian on the ground, plant a staff vertically, and

FIG. 133.



describe from its foot as centre several concentric arcs. A little before

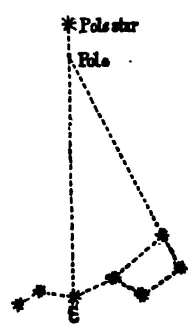
and after noon observe the course of the sun, and mark the intersections of the shadow of the staff with those arcs. Bisect in M, M′, M″ each of the arcs m n, m′n′, m″n″, &c., intercepted by this shadow, and those points M, M′, M″ belong to the meridian.

The meridian may also be traced directly on the minute by a similar process, by driving a pin, for instance, to replace the staff, but the minute should be placed in a position of parallelism (84).

If there is no sun, or if time must be saved, the prismatic compass gives us the magnetic azimuth of a line of the canvas, and we conclude the true azimuth by adding or subtracting the variation.

The polar star may also help us to trace the meridian approximately, for it is very nearly in the true meridian when it arrives in the same

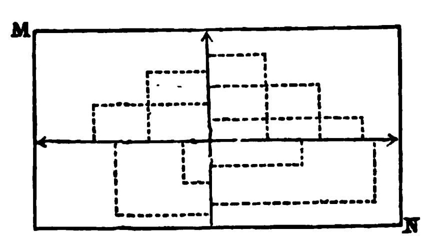
FIG. 134.



vertical as the star E of the tail of Great Bear. A plummet enables us to ascertain the position of verticalism.

(119.) When a survey is very extensive, several officers concur to its execution; the canvas is first made on a single sheet, and is afterwards transferred to the several minutes, but in order that those individual surveys may afterwards agree, the transfer of the points is made

FIG. 135.



by means of their co-ordinates referred to two rectangular axes drawn

across the canvas, representing generally a meridian and its perpendicular. Thus the canvas on M N is subdivided into four sheets; on which the details can simultaneously be filled in, and these four minutes being placed close together will give the general plan.

(120.) Having in hand a minute with several points fixed upon it by the triangulation, we proceed to fill in the details.

The prismatic compass is undoubtedly the most eligible instrument for that purpose, but one should not exclusively trust to it, because in case of accident, and accidents will occur in the field, the operations would be interrupted. A previous acquaintance with the plane table, or the chain, the sextant, &c., will in such case prove of great service; but above all the plane table should be well understood, inasmuch as being replaced by the minute itself (82) it can never fail us.

To survey the details with a prismatic compass, we station at a point from which they are easily reached, a crossing or change of direction of roads, the entrance to a village or wood, the corner of a wall or of an inclosure, &c. We determine on the minute the projection of that station by taking two or three bearings on the points already given (76), and we proceed as described for traversing; we frequently check our work by taking bearings on the points we have previously found; and by pacing the distance at every station to the various details, we successively introduce them, and even draw them at sight between two stations sufficiently close to each other. The method of intersection is to be had recourse to whenever possible.

To fill in with the plane table, we select the same points, and find our station as explained (84, &c.), introducing the details by intersection, by chaining or pacing, and traversing on the chief direction.

With a box sextant the operation is more troublesome, but the principle is the same.

(121.) Whatever instrument we employ, we must frequently verify our position on the survey by means of those points of which we are certain, otherwise the errors will rapidly accumulate.

We lay down the trees, embankments, ditches, rocks, &c., and indicate the various kinds of culture by initials, to figure them afterwards according to the conventional signs.

The chief objects to determine exactly among the details are the

roads, paths, openings through forests, rivers, rivulets, lakes, pools, fountains, streets, outline of towns and villages, isolated buildings, mills, churches, castles, bridges, &c.; and while filling in these details we note in our pocket-book all the information that will subsequently enable us to write our report.

For rivers, we follow one side by *traverse*, and determine the other by intersections; for rivulets we also fix some points of their course by means of bearings, and have recourse to the cross-staff (105) when advantageous.

For towns or villages, the outline is first surveyed, and the entrances of the chief streets accurately fixed: then we engage in one of those thoroughfares, and while traversing we protract every detail by pacing the perpendiculars dropped from them to the direction we follow. After this we start from a central point, such as a square, a church, &c., to the various outlets. The yards, gardens, &c., are subsequently drawn at sight. The masonry is marked by a thick line, and the houses are shaded, so as not to be confounded afterwards with the yards.

The woods and forests are plotted in the same manner: first the perimeter, then a road, then the various outlets.

It would be impossible to enter into the never-ending particulars of the filling in the details. A day spent in the field with a brother officer well acquainted with the practice of military surveys, will do more for the instruction of the beginner than volumes of text. The principles of planimetry are both simple and few; the instruments employed are easily handled; but it is left to the sagacity of the officer to make the best use of those tools by an intelligent application of the methods previously described. Nothing is more simple, and the problem becomes still easier if the surveyor brings to bear on his work all the accuracy allowed by the instruments he employs. Accuracy is a saving of time and trouble.

(122.) To complete the survey it is necessary to represent the undulations of the ground, and to give the relative height of every point of its surface, together with the direction of the acclivities and declivities.

To effect this we begin by determining the altitude of a few of the

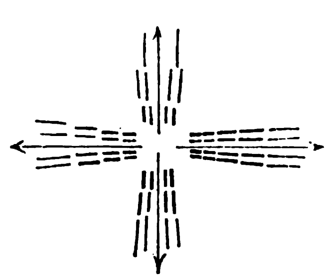
points obtained in planimetry, in order to form what we may call a canvas of levelling. If the altitude of one of those points is known, we obtain that of the others by means of the angles of elevation (110). If it is not known, we assume a certain value for it and calculate the others; for in military surveys all that we require is the relative height of the different points, and it matters but little whether it is possible or not to obtain from a map or any other source the true elevation above the level of the sea.

(123.) Having carefully established this canvas, we proceed to fix the position of the highest and lowest points of acclivities, that of ridge lines, thalwegs, cols, and of all points at which there is a change in the intensity of the slopes, which have not already been determined in planimetry. Their accurate position on the minute is indispensable for fixing the projection of their respective distances.

This done, we station with the clinometer at the points of known altitude, measuring the angles of elevation or depression, and by means of the formula $H=D$ tang. a, or the table (110), or even by a simpler process (112), we find one by one the altitudes of the various points which have been enumerated, and it is advisable to verify the altitude of the important points by means of two others.

(124.) When this is completed, we figure the undulations by the contours, an operation which is much simplified if we have, while stationing on any point, indicated the direction of the slopes. In fact, an officer accustomed to survey will have done so even in plotting the planimetry. The best way to mark this indication is to look in four

Fig. 136.

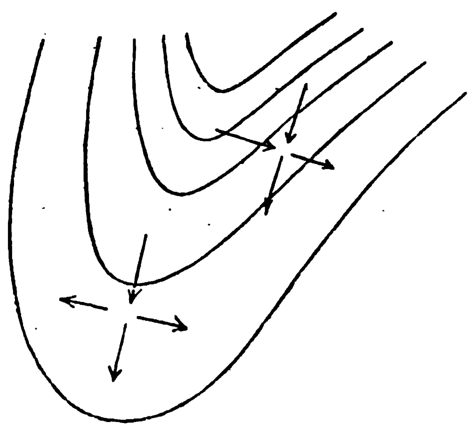


perpendicular directions, and figure by little arrows the direction

of the slopes; a few hachures more or less thick, or a few contours more or less close as the slope is more or less steep, will suffice. To estimate the direction and steepness of a slope, we must stand on it, and examine only a small extent, otherwise the effects of perspective will lead to error.

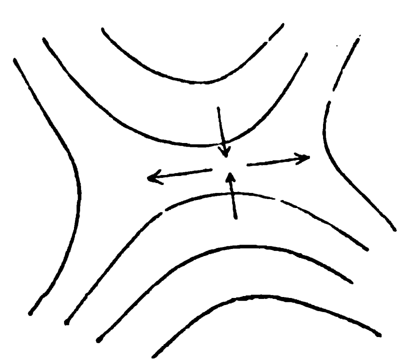
The four directions are quite enough; if the four are descending we are on a hill; if three descend and one ascends, we are on a ridge

FIG. 137.



(Fig. 137). If two contiguous ones ascend and two descend, we are

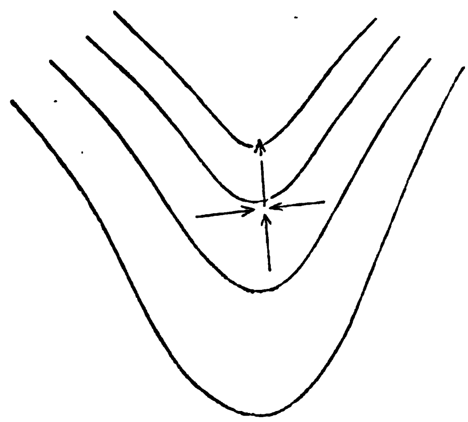
FIG. 138.



again on a ridge. If two alternate ones ascend and two descend (Fig. 138),

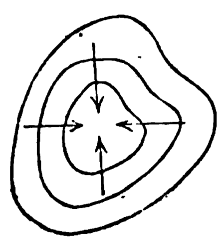
we stand on a col. If three ascend and one descend (Fig. 139), we are on

FIG. 139.



a thalweg. Lastly, if the four ascend (Fig. 140), we are in a hollow. These rough indications, with which we soon become familiar, are

FIG. 140.

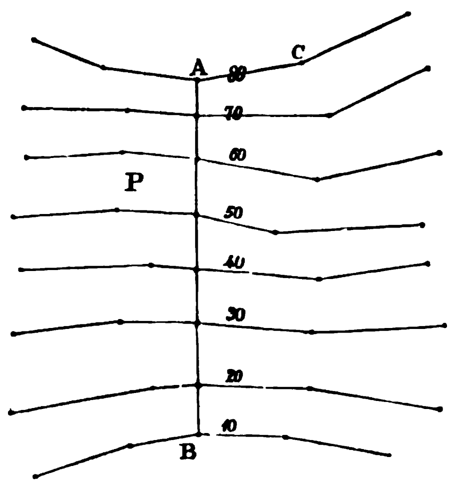


exceedingly useful in helping to connect the undulations of the different stations; and an experienced surveyor will, by their means alone, and without ever seeing the ground, represent its surface tolerably well.

(125.) Two methods are in use to trace the contours. When they must be traced with rigorous exactitude, as it sometimes happens in the survey of a site intended for fortifications, we have recourse to a water-level. To be clear, let us suppose that the altitudes of A and B (Fig. 141) have been found to be respectively 80 and 10, and that the equidistance (21) is 10. Between A and B there will be six contours. Divide A B into seven parts having altitudes, 20, 30, 40, 50, 60, 70, and plant a staff at each. Now, stationing at any point, P, set the level right, send a man with the levelling-staff at A, and note

the reading. The man moves afterwards in the vicinity of A, until the same reading be again in sight with the level: the point C, where

FIG. 141.



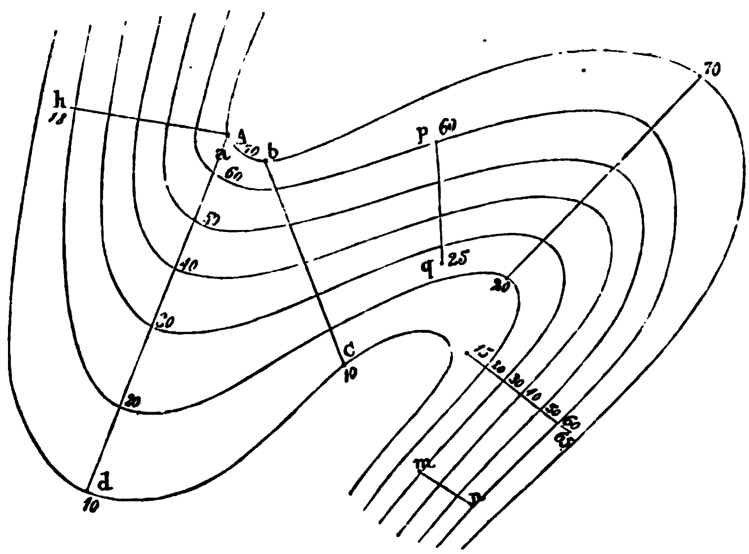
this occurs, is evidently on the same level with A, and the man plants a stake thereat: on he goes, and as many points as are wanted are fixed in this manner. The same operation is repeated for contours 70, &c. Having thus traced the contours on the ground, they are plotted on the minute, with the help of the prismatic compass to take the bearings of the stakes.

This method is long and tedious, therefore the second will be preferred as more expeditious, and sufficiently accurate for general purposes.

(126.) Suppose that the altitude of the points a, b, c, d, e, &c. (Fig. 142), has been ascertained (122), and that the equidistance=10 yards. Join those points by straight lines. The point a is on a contour, but h is not, and there will be five contours between it and a. Divide a h into six parts, five of them equal, and the rest only $\frac{2}{10}$ (Euclid, p. lvi.), the contour will pass through the points of division. Again, take b c, and divide the line into six equal parts, if the sketch (124) indicates a uniform slope. Along a d the sketch implies a greater declivity towards a; divide, then, a d, by sight, into six unequal parts, the smaller being nearest to a; divide m n into three equal

parts, and if the sketch indicates a continuance of the same slope above n and below m, carry another division beyond those points, and so on.

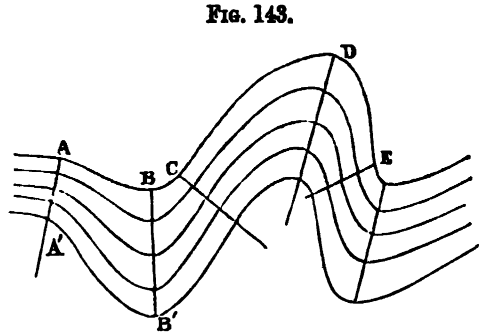
Fig. 142.



The points of same altitude are afterwards connected by a continuous line.

(127.) The clinometer of Trinquier will here be found very convenient. By means of the pins of the movable diameter (115) which determine a horizontal line, we can trace one contour as already explained (125). Let A B C D E be this original contour, and let

Fig. 143.



the equidistance be five yards. Stationing at A we aim with the horizontal slit along the steepest line of the slope (or the less steep, as the case may be), as far as we can see the dip uniform. Let the

angle of depression be 25° (Fig. 128). The parallel 10 intersects the movable diameter at a point corresponding to perpendicular 11 of the fixed diameter. This shows that for a distance of 110 yards the vertical fall is $10 \times 5 = 50$ yards, or that for 11 yards measured horizontally the dip is 5 yards. Hence, if on direction A A′ of the dip, placed on the plan by means of the compass, we take parts of 11 yards each, we obtain as many points belonging to the contours required. Stationing now at B, we repeat the same operation: if the parallel 10 intersects the movable diameter at a point corresponding to perpendicular 20, then on B B′ the contours will be 20 yards apart, and so on.

(128.) The operations of levelling as described here should be made by beginners *after* they have completed the planimetry: but when they have, by means of practice, acquired a fair acquaintance with the forms of the ground, they may venture to conduct planimetry and levelling abreast. In military surveys they will be expected to do so, because the exactitude of the contours is not necessary, the chief thing consisting in indicating the relative heights, so as to distinguish those practicable to the three arms from those that are not. Therefore, whenever making a station in the field, we must sketch the features of the ground around it, and when repairing from one station to another, endeavour to connect those indications by slight touches of the pencil, to be afterwards modified when the clinometer shall have come into play, and given the altitude of a few stations on the thalwegs, ridges, summits, cols, &c. Let us here more than ever beware of the field book; never trust to memory if we can help it, and constantly draw the features from nature. There lies the real study of topography.

(129.) When a survey is made for a special purpose, it is customary to compile a memoir to complete the description. The table (141) contains all that is necessary.

CHAPTER X.

MILITARY SKETCHING.

(130.) It very seldom occurs that in the field we have either the time or the means of executing regular surveys; and as plans are necessary to guide the movements of troops, prepare their encampments, select positions, combine attacks on field works or passages of rivers, &c. &c., it becomes indispensable for officers on the staff to make those plans or sketches either without instruments, or merely with those that they can construct themselves on the spot.

Nothing is impossible, especially in topography; and whatever be the circumstances under which an officer is placed, he should never give up an attempt as useless until he has tried. And if he tries, he will succeed.

Referring to the foregoing chapters, all that is required to make a plan is to measure distances and angles. For distances, we have three means—our pace, the trot of a horse, or our watch—the first of which cannot fail. For angles, if a prismatic compass or a sextant cannot be found, a plane table can be improvised, and it is indeed a capital instrument. A cross-staff and a clinometer are made in a few minutes. If we employ this rough table a pin fixed into it shall provide us with a sundial which will still simplify the operation. With paper, pencil, india-rubber, and a knife, we have the wherewithal to proceed.

A previous acquaintance with the principles of topography, and a fair amount of practice in regular surveys are indispensable, since in every sort of sketch the art consists in making the best possible attempt at imitating the regular process, according to the resources at hand. A few words will be sufficient to point out what is to be done when we have contrived to extemporize our instruments, and have time enough to take measurements, or when, being hurried, we have scarcely time enough left for that purpose.

(131.) The first step to be taken is again to select a base and form a canvas. Sketches are generally made at the scale of 4 inches to the mile, but we adopt the scale of paces and construct it at once. If a map can be obtained we transfer the base as well as the canvas on our minute, selecting for vertices of the triangles the steeples, windmills, bridges, or crossings of roads. But as this is possible in Europe only, we are almost always compelled to measure the base and to construct the canvas by one of the methods which have been explained: if the country is woody or barren we plot the triangles by pacing—a long but then indispensable process, which can nevertheless be simplified in employing men to signal remarkable trees or to stand for points of triangulation.

(132.) The details will afterwards be filled in, and as this operation will be so much the easier when the canvas is well and closely executed, we could not pay too much attention to its construction. The methods of intersection in open countries, that of traversing in woody ones, are successively or simultaneously employed. Starting from one station we proceed to the next, drawing details at sight, right and left of the direction we follow, occasionally climbing a tree to discover them better.

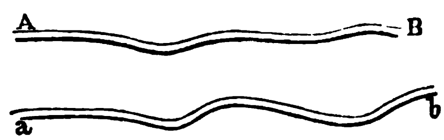
With regard to the representation of the relief, the canvas contained some points on the characteristic lines of the undulations, thalwegs, ridges, and on summits. An arbitrary altitude being assumed for one of those points, the height of the others will be ascertained by means of the clinometer. The details of the relief will be plotted by figuring at every station the lines of contour and the directions of the acclivities (124). It would take more time to describe all the operations of such a survey than to make one. We shall therefore confine ourselves to a few remarks.

(133.) The details of every triangle are filled in by following first the direction of the perimeter, then a direction either road, thalweg, or ridge, running across it, laying down the details at sight, subdividing the triangle into two parts. Those are again subdivided in the same manner until the parts become sufficiently small to permit drawing at sight whatever they contain.

We should not hurry in attempting to represent too much at

a time on both sides of the direction we traverse; it is far better to indicate them slightly at first, and definitively plot them when their position has been verified by that of the other roads or directions between which they are contained. These roads should be traced according to their general direction; this is important, inasmuch

Fig. 144.

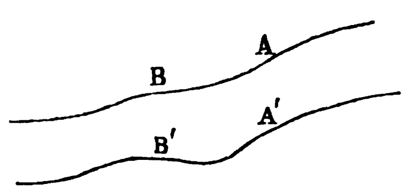


as there is a tendency among beginners to exaggerate the windings and to represent the road A B as a b.

For a village, it is advantageous to make a preliminary reconnoitring from the top of a high building or a steeple. We trace its chief street; then, if possible, two streets at right angles: after this, we take the perimeter of each part, and subdivide it till the details can be drawn at sight. The same of a wood.

In figuring the relief, we should remember that we have a great tendency to exaggerate the importance of the acclivities on which we are placed, especially when the ground presents slopes alternately

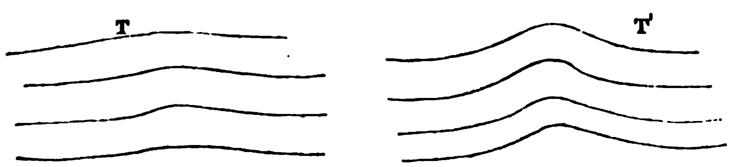
Fig. 145.



gentle and steep; so much so that the slope B A is often estimated to be on the opposite, A′ B′.

When following a thalweg, T, slightly pronounced, having for

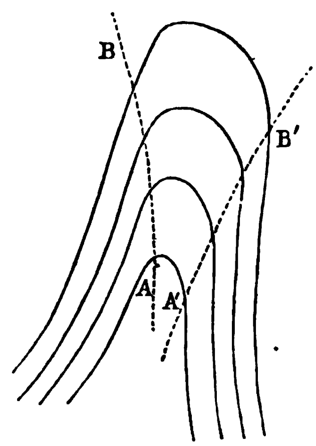
Fig. 146.



instance a mere depression of two yards, we are inclined to exaggerate it as in T′.

We are also invariably inclined to open the valleys too much, and this may be avoided by determining carefully the position of

FIG. 147.



the lines A B, A′ B′, on which the slope of the sides changes its direction.

(134.) When the enemy is close by, a survey at sight or a sketch is the only representation that can be made when any information is needed respecting the ground, and as time becomes precious, the foregoing operations can no longer be made. Here the *coup d'œil* is indispensable, and if an officer has not by a long practice become familiar with valuing distances and angles at sight, he will fain attempt such a reconnoitring.

Although such surveys generally embrace but a limited extent, since they would otherwise be far too inaccurate, yet a method of measurement should be adopted, because perspective would tend to accumulate errors upon errors—there being no absolute, but only relative, dimensions for the eye.

The means employed differ but little from those employed in topography. We select and measure a base, and connect it with the different points of the surface by climbing a tree or ascending a culminating spot. Or we select three conspicuous objects, measure by

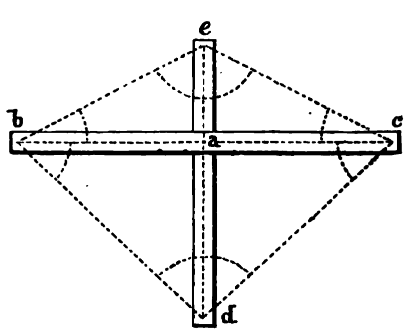
time their respective distance, and plot the triangle at the scale. Starting from one of the corners, we advance towards the other, drawing at sight all the angles. Having done so round all the perimeter, we proceed to the interior. The undulations are figured at the same time, but, as it is only necessary in this case to "accuse" the relative heights, this is done by making the hachures thicker when the slope is steeper. Numbers 1, 2, 3 may be inscribed on the minute to denote the heights in relation to their importance. Great attention is paid in distinguishing the acclivities practicable to infantry, cavalry, and artillery from those that are inaccessible.

Perspective leads to many illusions; a steep hill appears nearer than it is. In some instances distance seems greater at dark or in foggy weather—a smooth object appears nearer than a rough one; the dimensions seen from above seem smaller than those seen from below. No attempt should, therefore, be made to guess beyond a mile.

(135.) The officer who is liable to be called on to execute this sort of survey should exercise his sight, and know at what distance he no longer distinguishes a man, a horse, a tree, a house, &c.; this alone may help him greatly.

Angles must be guessed at. Among the many means employed to obtain them, we may notice the following:—

Fig. 148.



Two pieces of wood, two rules, for instance, are fixed together at right angles in a: the side a b = a c = a d, and a e = ½ b a = ½ c a. Pins being planted at b, e, c, d, this contrivance will be employed as the staff cross (97); it gives several angles—b d e = e d c = c b d =

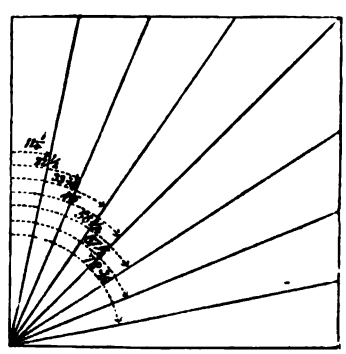
b c d=45°; e b c=e c b=30°; b e d=d e c=60°; e b d=e c d=75; b d c 90°; b e c=120°. It is the *winkel kreutz* of the Germans.

A foot-rule with a hinge, or a piece of paper folded, may serve to measure and trace the opening. A square piece of paper folded in

FIGS. 149 and 150.

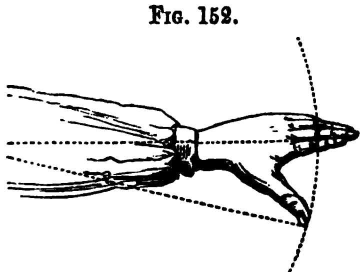
half along A B, then folded in $\frac{1}{4}$, $\frac{1}{8}$, &c., gives angles of 90, 45, $22\frac{1}{2}$, $11\frac{1}{4}$ degrees; and those of $78\frac{3}{4}$, $67\frac{1}{2}$, $56\frac{1}{4}$, $33\frac{3}{4}$, are obtained in opening all but one or two, &c., of the folds.

FIG. 151.



The forefinger and thumb of the arm extended to their utmost stretch subtends about 11°.

FIG. 152.



These auxiliary means will guide the observer, but he should exercise himself in guessing at a few angles round the whole space, and

correcting his valuation by the excess of their sum over 360°. Taking first 4 angles, then 8, then 12, his eye will gradually gain experience. Indeed, it is surprising with what accuracy some practised officers value a series of angles at sight.

(136.) Among the many cases that may occur, the reconnoitring of a road (77) through which a convoy or a detachment will have to pass, happens frequently. It is accomplished by traversing, guessing at the angles formed by the windings, and sketching the details at sight within a few hundred yards on both sides. This sketch, or *itinéraire*, as it is called, is accompanied by a report giving the distance between the most remarkable points, such as villages, defiles, bridges, ascent, descent, change of direction, buildings, cross-roads, &c. It will state the time employed to perform the journey, give the width of the road, indicate its nature, &c. The objects having military importance should be described: villages, houses, rivers, bridges, fords, &c.; the accommodation for man and horse either on the march or in permanent quarters likely to be found in the villages; the means of transports, such as horses, carts, ferries, &c.;—in a word, everything we can learn or see should be noted. (See 141.)

(137.) It may happen that an officer has not even the time to survey in this manner, and that he is placed in such a position that he cannot ostensibly make use of his pencil. This most generally occurs under very important circumstances—in the proximity of, if not under the very eye of the enemy. To memory alone he must trust; therefore it is indispensable that he should understand thoroughly the object of the reconnoitring, in order to concentrate his attention on those points of the ground which possess importance. He should notice the time he took to walk or gallop to the chief points. He examines the state of the roads, the direction and inclination of acclivities, the rivers, rivulets, and their embankments, &c. &c. Returned at the camp, he should plot the chief objects in traducing the time into distance, and group the details around them. This sort of survey is closely connected with military art—in fact, it belongs to it.

(138.) A rough sketch may even be had from mere indications, previously to entering a country occupied by the enemy: spies and inhabitants, especially guides, hunters, carriers, muleteers, shepherds, &c., are

examined separately and cross-questioned as to the roads and paths, the places they lead to, the obstacles, defiles, woods, hills, rivers, marshes, bridges, &c. The sketch is made under the eyes of the informer, marking the distances in time, and it is successively rectified.

(139.) *Reconnoitring* is the *ensemble* of the operations necessary to obtain information on the nature of the country on which the war is carried, on the resources it affords, or on the forces and positions of the enemy.

Generally, reconnoitring will consist of two distinct parts, 1st, a plan or sketch; 2nd, a report.

According to circumstances, the sketch will be one of those we have described.

As for the report, it should contain a brief account of all that bears upon the end in view, distinguishing *most* scrupulously that which has been seen from the information collected from various sources, but not verified personally.

An officer entrusted with a reconnoitring receives some special instructions from his commanding officer: to them he must implicitly conform, without attempting to swell his report by details unconnected with the purpose of the reconnoitring. It is not an easy task, to seek for, to take, and to collect the information required; it implies a vast experience: therefore, to accomplish it with credit, we should during peace prepare ourselves by several exercises on the ground, and by reports on some special cases connected with the arm of the service to which we belong.

To take and collect information at home is difficult, because when the inhabitants perceive officers engaged in the act, they grow suspicious lest some new billeting or some tax be imposed upon them: but in a hostile country it is far worse—so much so that they conceal all they can, and invariably affirm that the "environs" of their village are impracticable; hoping thus to deter the troops from approaching them. Even when of good faith they give out to be practicable the regular roads and paths only, and consider as great obstacles the ploughed lands, hedges, ditches, &c.; so that it becomes necessary to multiply the investigations in order to ascertain the truth.

While executing the plan or sketch, we collect and note all that

we see: we question guides, shepherds, carriers, as well as mayors, bailiffs, &c.; examine the maps in existence, the statistical, historical, and military works written on the country under investigation. If none can be found, we endeavour to extract statistical information from the inhabitants themselves—this skilfully and indirectly—avoiding to frighten them or to rouse their suspicions. To this end a fair knowledge of the language of the country is indispensable.

(140.) For officers who have not yet acquired some experience in writing reports on reconnoitrings, we give a table of the different subjects to be examined in the most general cases, as adopted in the French staff. They are enumerated in the order in which they should be treated. It will be sufficient for the most extensive memoirs, and for any special case, such as the reconnoitring of rivers, roads, &c. The points to which attention should be directed are found under the proper heading, if they are not mentioned in the order given at starting.

This report is written legibly, with conciseness and lucidity. Proper names should be carefully spelt. The order in virtue of which the operation has been made is transcribed at the head of the manuscript, which is made up as a report, not as a letter, and signed by the officer.

§ I.

Physical Description.

(141.) *Geographical Position of the Ground reconnoitred.*—Approximative limits between which the ground reconnoitred is enclosed. Latitude, longitude, and if possible, altitude of the chief point; general watershed; boundaries of the coast, of the watershed; principal basin to which the ground belongs.

General Configuration of the Ground.—General aspect; mountainous, hilly, or level; open or wooded; of easy access, or intersected with obstacles, hedges, ditches, enclosures, walls, rocks, &c.; covered with bares or heath; dry or marshy.

Basins, Orography.—Basins in which the ground lies. Chains of mountains and their ramifications; chains of hills and of secondary heights; of what description. Table-lands, their form and area. Direction of the watershed lines; remarkable points through which

they pass; greatest altitude; table-lands or heights across which they run.

Valleys, vales, ravines, defiles: their dimensions; height of the sides, and steepness of their acclivities; great undulations which destroy their regularity or obstruct the circulation; eminences or buttresses narrowing or running across the valleys; forests; lakes; marshes; &c.

Plains.—Level, undulated, intersected with hills, ridges, bares, marshes, &c.

Maritime or fluvial islands.—Their dimensions; mountainous, flat, marshy, or sandy; wooded; cultivated or barren; inhabited or not; towns, villages, anchorages; to be described as a continent when their surface is uneven; floating islands.

Hydrography.—Rivers and streams running across the ground reconnoitred; their source; total length of their course; chief towns situated on their banks; their mouths or confluences; principal tributaries.

On the ground reconnoitred itself: breadth and depth; variations they are exposed to at different seasons; parts where the river is fordable, and its depth; variations of the bed; places where the stream branches off; importance of the branches; height of the banks; fall per mile; sudden variations in the channel, falls, rapids, eddies, rocks; velocity per hour; periodical or accidental rises; their cause; time at which they take place; their height above low-water mark. Inundations: how far they extend in the valley; mention of extraordinary floods, and the places which suffered most; how to prevent their recurrence; dams, sluices, &c. Nature of the bottom of the river: rocky, gravelly, sandy, muddy. Nature of the banks: their form; flat, gently or rapidly sloping, abrupt, overhanging; height above the water; covered with stones, woods, meadows, reeds, or gardens. Command of one bank over the other; constant or alternate.

Canals: their name; where they lead to (see § III.).

Lakes: their dimensions; nature of the bottom and of the banks; fordable parts; navigable parts; ports, capes, isthmuses, and other peculiarities.

Ponds: artificial or natural; permanent or not; easy to empty or

otherwise; if the bottom be practicable for troops; produce of fisheries, cultivation; influence on the health of the inhabitants.

Marshes: produced by streams or by springs; covered with water or mud; their extent; if there be any secret or open communication across; possibility of draining them. Bogs: their extent; passable or not; if turned to any account.

Swamps, pools: how made use of by the inhabitants; their influence on salubrity.

Fountains and springs: whether numerous and of abundant supply; potable, saline, or muddy water; chief ones to be indicated; their temperature, when it differs sensibly from that of the atmosphere; use the inhabitants make of them; remarkable peculiarities; intermittent and spouting fountains, &c.

Cisterns, artificial or natural wells: if they give a sufficient supply to the inhabitants. Artesian wells; their depth; abundance and quality of the water. Pits.

Sea Coasts.—Configuration of the coast: cliffs or downs; their height and shape; if worn away by the sea; marshy, gravelly, or sandy shore; even or undulated beach; natural ports, harbours, anchorages, roadsteads, creeks, bays, &c.; points favourable for landing; advantages for navigation; works of art constructed to resist the encroachments of the sea; depth below which the vessels cannot enter the port; sands and bars near the coast and at the mouth of navigable rivers—this mouth to be described; difficulties attending the entrance of vessels into, or their egress from, the river, either on account of the ground or the winds and tides; mention if the bars are changing, and if the passage is more practicable at one time than at another; lights and signals, either extant or to be established.

Nature of the Soil at the surface or at different depths. Grottoes and caverns; their extent; to what account they could be turned. Subterraneous streams and lakes. Geological composition and mean thickness of the vegetable soil in the plains and on the acclivities.

Volcanoes, either extinct or in activity; volcanic formations. Craters, their situation, height, and shape. Basalts, lava, dross, &c.

Ores of every description, either under work or not. Mines;

coal mines; their depth, number, and thickness of the strata; quality of the products.

Quarries of marble, stone, chalk, gypsum; those that are worked; quality of the products.

Mineral and thermal springs; nature and quality of the water; the account it is turned to.

Salt pits; salted springs; salt marshes.

Aerography.—Climate; warm, cold, dry, damp. Mean barometric pressure. Temperature of the various seasons; mean temperature; greatest cold; greatest heat.

Number of wet days; mean quantity of rain falling in the year; how long the snow remains on the ground; rivers which freeze so as to bear loaded carriages.

Prevailing winds. Fogs. Properties of the air and water with regard to the health of men and animals. Endemic diseases; causes of insalubrity; how to remove them. Meteorological facts—Violent and frequent storms, hail, waterspouts, &c. Plants and animals peculiar to the climate—Rye, wheat, rice, vines, orange trees, cochineal, &c. Forests—Fir trees, &c. Race of men, of mammalia, reptiles, &c. Tides—Their chief peculiarities; limits of high and low water in the ports and the rivers.

§ II.

Statistics.

Political and Administrative Divisions.—Ancient provinces of which the ground reconnoitred has made part. Administrative, judicial, ecclesiastical, military, maritime, and financial circumscriptions. Counties, departments, cantons, provinces, districts, unions, parishes. Courts of appeal and sundry tribunals. Dioceses, consistories. Universities, academies, consulships. Sundry services—Postal service, high roads. Mines. Woods and forests. Custom-houses for direct and indirect taxes. Divisions or military stations—Artillery's head quarters; engineers' head quarters. Maritime prefectures, districts, and quarters.

Population.—Total population of the canton, parish, district, or

other circumscription. Distribution of the population between the towns and country; between agricultural and operative pursuits; between mountainous and level countries. If the population is increasing or decreasing. Comparison between the existing and a previous state. Causes of the movement of the population. Number of inhabitants per square mile; number of families. With regard to recruiting, compare the number of men with the amount of the population. Proportion of men declared fit for service to those examined. Average height of recruits. Proportion of men fit for the special arms of the service—artillery, cavalry, &c. Height, physical constitution, character, manners, way of living and dress of the inhabitants.

Differences or homogeneities between the inhabitants. Sympathies or antipathies between divers classes of the population, and divers localities. Aptitude of the people for war, arts, sciences, commerce, or agriculture. Emigration—Workmen going to other countries, or coming from neighbouring states; for agricultural or industrial pursuits; extent of emigration.

Militia, Yeomanry.—Organization into legions, regiments, battalions, squadrons, or companies of cavalry, infantry, artillery, firemen. Force per county, district, parish, or other circumscription. Number of men forming part of the reserve of the army with unlimited leave of absence. Maintenance and state of the armament at the charge of the states, communities, or private persons. Clothing. Parts of the militia wearing uniform. Degree of military instruction. Aid which the armed population would afford in case of need.

Language.—Languages and dialects; parts of the population who speak them. Usual way of spelling the names of places; their pronunciation, when it differs from the ordinary language; etymology of the names of the principal places. Characteristic words to be found in the language of the country. Examples.

Religions.—Divers sects; number of inhabitants comprehended in each; their reciprocal disposition.

Public Instruction.—Degree of instruction of the different classes of the population ; proportion of literary persons. Schools of all sorts. Literary wealth of public libraries. Universities. Academies. Learned societies.

Public Buildings.—Churches or temples, castles, town-halls, courts of justice, colleges, seminaries, museums, libraries, exchanges, markets, light-houses, prisons, &c. Remarkable houses or buildings; their construction or their historical importance. Their use and capacity. Objects of art esteemed.

Houses.—Different habitations, country houses, farms; their general distribution and size; if built of stones, bricks, earth, wood, &c.; tiled, or thatched.

Resources for Lodging Troops.—Estimate of the resources for men and horses. For troops on the march or quartered; whether in military buildings or other public establishments, or in private houses; large buildings fit for the reunion, in a case of emergency, of a large body of men or horses. Localities in which small buildings only are to be found. Military establishments, hospitals, parks, magazines, &c.

Materials of Construction employed in the Country.—Marbles, stones, bricks, udders, &c.; timber and other woods; metals; quarries whence the materials are extracted.

Statistics of Towns.—Capitals of counties, departments, fortified places, garrisoned or maritime towns, and all towns having more than 3000 inhabitants. Situation—Advantage of the position of the place, whether as a fortified place or a centre of industry, commerce, &c.; as a seaport, on a river, on a railway, at a cross-way, in a fertile country, &c.; its distance from neighbouring towns; aspect of its buildings in general; their mode of construction, resources which they would offer for the different military services. Enclosed or open towns; shape of the enceinte; ancient or modern fortifications; walls; enclosures; divers authorities who sit in the towns; details of the population; on the various public establishments; distribution of the waters; industry; commerce; celebrated men of the country.

Particular statistics of fortified places; system of fortification; number of fronts of the enceinte, outworks, ravelins, counter-guards; detached works—their form and importance; if the place is protected by a river, by inundations, marshes, escarpments, &c. Military buildings bombproof; casemates, resources offered for all military services by private buildings and houses.

Agriculture.—State of the agriculture of the country; general

aspect of the situation; progressing or falling off; quality of the soil, wheat, rye, or barley land; vineyards, meadows, woods, &c.; high or small farming; methods of cultivation, whether by horses, cattle, or hand; harvest rotations; customary crops of the land; artificial meadows; varieties of agriculture; proportion of the sowing to the reaping; produce per acre of cultivated lands, meadows, vineyards, orchards; mention the various products—hemp, linen, oleaginous plants, beetroots, tobacco, &c.; ratio between the production and consumption.

Woods and Forests.—Forests of public domains; public and private woods; what natural productions predominate; high forest-trees, copse, or underwood; regulations adopted for cutting; statement of the size and condition of the forest; thickets, glades, cultivated lands, meadows, ponds, and habitations which they contain; their products; practicable or not for troops, for artillery; cross-roads, trenches, water-courses, ravines, ditches; wood fit for ship-building, or cooperage.

Cattle.—Different races of horses; the breed progressing or decreasing; qualities and faults of these races; approximate number of the kind fit for military service; saddle and draught horses; paddocks, stallions' depôts; number of horses they furnish; mules and asses in the country; bovine race; number of heads of this race compared with the population and the wants of agriculture; its qualities; fleecy beasts; existing races in the country; approximate number of heads or of flocks. Goats, only when they are in flocks.

Products of the poultry yard, the chase, and fishing (when commercial); fowls, pigs, game, fish; butter, eggs; dairies, cheese-markets, bee-hives, oil, fruits, &c.

Industry.—Hand-mills, wind-mills, water-mills, steam-mills—their situation and productions; other mills; oil-mills, tan-mills, saw-mills, &c.—Paper factories; their production; hand or mechanical fabrication; founderies and metal works; salt-pits; wool, cotton, linen, silk, hat, rope, tan, &c. Factories—china, pottery, bricks, tiles, &c.; works—their importance; number of workmen they employ; works made by hand, with horses, water, steam. Annual natural productions; annual time of rest.

Local measures of length, superficies, wegiht, capacity; their relation to standard measures.

Commerce.—Agricultural, industrial, native, exotic productions. For consumption, importation, exportation, transit; docks, warehouses, &c. Annual variations of import and export; fairs and markets for grains, beasts, &c. At what time they take place; their importance.

Public Revenue.—Direct and indirect taxes; custom-houses, &c.; outline of the working of the establishment of taxes; revenues from domains belonging to the State; do. of the branches of industry and commerce of which the State reserves to itself the monopoly; resources of credit.

§ III.

Communications.

General Outline.—Network of the communications; high roads of divers classes, roads more or less numerous, more or less practicable; railways; navigation; telegraphs.

Land Communications.—Details concerning each of the high roads most important for military operations which are to be mentioned in the Mémoire; general direction, breadth; paved, strengthened with flints, or, in the old way, on natural earth; sided with trees, hedges, ditches, walls, poles; hollow or banked up; slope for the drag; low parts which could be overflowed; other causes for accidents; defiles; facilities or obstacles for waggons; distance between one town and the other, and to those to which the road leads; how frequented; post inns, public vehicles, waggons. Means for repairing to be found in the country; parts of the road running upon old Roman ways.

Roads of Second Order (?)—Principal details of the preceding article according to the military importance of the routes. Divers routes—on fascines, on ice, &c., &c. Neighbouring roads fit for waggons as distinguished from those merely destined for beasts of burden or foot soldiers. Footpaths.

Railways, either constructing or worked; principal towns they pass through; where they end. Branches. Importance of a terminus as a point of concentration. Lines, with one or two sets of rails. Distance from one terminus to the other; total length. Slopes or inclination of the ways. Obstacles that they pass—Rivers, mountains,

forests, &c. Appointed time for the journey. Mode of construction—On soil, viaducts, arches, or tunnels. Engines. Employment of the railroad for the transport of travellers, merchandise, or for manufactures and metals. Influence of each of these roads over military operations (subject of § IV. of the Mémoire). Railways in project.

Navigation.—Details on each of the practicable rivers: limits and extent of the navigable or floatable parts; ports or landings; impediments or accidents of the ground which hinder navigation. Works of art for keeping up the navigation: dykes, sluices, locks, cuttings, weirs, &c.; cleansing, repairs, &c.; annual duration of the time of rest.

Number, dimension, and draught of water of the boats; burden in tons of the boats navigating by sails, steam, or by being towed; valuation of the annual transport of travellers, provisions, agricultural and industrial, native or foreign merchandise.

Canals.—Details about every canal passing through the ground reconnoitred; name and ends of the canal; if with points of division; lateral to a river, or joining two navigable ways; of great or little navigation; length, destination, and importance of the canal; chief towns it passes through; breadth at the level of water; depth; nature of the country it passes through; rivers or other waters which feed it; works of art for the canal, dykes, sluices, locks, &c.; distance between the sluices or locks; height of the fall at the locks.

Boats, and amount of navigation, as for rivers.

Maritime Navigation.—In ports, establishments of the royal navy, ships of war or belonging to the State. Number and tonnage of merchant vessels, of vessels that sail in and out annually. Number of sailors; seamen attached to the colonial or distant trade, to the coasting and fishing trades.

Means of passing Rivers and Canals.—General considerations on the points of passage. Existing bridges; their situation, length and breadth, their destination; their construction in stone, iron, wood, &c. Suspension-bridges of one or more arches; for carriages or foot passengers only; tolls. Drawbridges; lifting or turning bridges; small and foot bridges. State of repairs; means of repairing which the country affords. How to destroy the bridges.

Ferry boats, flying bridges. Time necessary for crossing. Number of men, horses, and waggons, that they can transport.

Fords, permanent or moving; their direction, perpendicular or oblique to the stream; quality of their bottom, rock, gravel, fixed or moving sand; their length and breadth; if they are fit for the passage of artillery, cavalry, or only infantry; means of rendering a ford impassable.

Convenient sites for military bridges, pontoons, boats, easels, &c.; length which those bridges would have; facility of approach; passage on ice.

Telegraphic Lines.—Aerial and electric telegraphs. Direction of the line. Principal towns where the wires end. Telegraph stations existing on the ground reconnoitred.

§ IV.

Military Considerations.

Offensive.—General character of the ground reconnoitred considered in a military light; advantages offered for operations by the great obstacles, communications, and points of support of which possession can be taken. Great lines of operation, sketch of the same; openings and masses of resistance. Secondary lines of operation. First and second-class strategic points to occupy. General outlines of the works of fortification and others to be proposed. On the maritime coasts; advantageous points for landing; tonnage of the vessels that can land; difficulty of approaching the coasts through winds, tides, &c.

Defensive.—Extent of the frontier in length and depth; general disposition of the ground; great undulations; openings; masses of resistance; lines of defence; protection to be derived from them; lines of operations by which they are intersected; strength of the chief base of operations, owing to the nature of the ground or to fortified points. Points of support for defensive operations. Communications (besides the great strategic lines already spoken of) perpendicular or oblique to the frontier that are more or less practicable; how to defend them. Probable direction of the attacks of the enemy; of an

invasion. Means of resistance to oppose him, or system of defence proposed in the Mémoire, according to the configuration of the ground, the communications, the defensive resources existing, and the military operations which the ground would allow of.

In countries difficult of access, mountainous, or covered with forests, thickets, or defiles; advantages of their organizing a guerilla warfare. Facilities for divers kinds of ambuscade; points of concentration, rallying-points. Resources of all kind (men, provisions, means of transport) to be drawn from the country and the inhabitants for this kind of war.

Near the coasts; maritime attacks to which they are exposed; points of landing to watch; system of defence to propose.

For the interior of the territory; lines of defence in the rear of the former; protection they would offer against the probable march of the invasion. Additional means of defence. Masses of resistance to be turned into account in the defence; works they would require. Defensive points to organize. Points of concentration of the movable forces, of the reserves. Decisive points of the theatre of operations.

Positions.—Positions for a *corps d'armée*, a division, a detachment more or less considerable, covered by natural obstacles or to be entrenched. Fields of battle, site for fortresses, entrenched camps, divers posts, &c. Details on the positions which the ground encloses, their action on the general defence; distance to the neighbouring fortresses; extent of the front, depth; obstacles covering the flanks and front; communications and lines of retreat more or less practicable; troops of all arms necessary to the defence of each position; safe site for the parks; advantage to be derived from cities, villages, castles, churches, cemeteries, for defence or shelter; places from which provisions, forage, water, and wood, could be drawn.

For a fortified or a maritime town: full information respecting the particular statistics, and application to this place of the above considerations; advantages or inconveniences of the disposition and construction of the works; flanking fire; defilade; strength and capacity of those works; their state of repair; front or fronts of attack; description of the environs, and statement of the difficulties for an enemy who undertakes the siege. For maritime places: if the naval establishments are

exposed to the effects of a bombardment, or of a fire from steamers or rockets; means of preserving them from the effects.

§ V.

History.

General History.—Statement of the principal political events that have taken place in the country where the ground reconnoitred is situated. Origin of the remarkable cities or of the actual population. Changes of governments the country has undergone; dominions under which it has passed. Great disasters that befell it. Celebrated politicians, or military men who influenced the state of the country.

Archæology.—Remaining monuments of the various epochs, Greek, Roman, Christian, &c. Each epoch divided into three classes—Religious monuments, military monuments, civil monuments.

Cities or villages, strongholds, castles, ancient camps, temples, &c.; their position, description, vestiges that remain of them. Authorities from which the description is taken, historians, drawings, traditions of the country, &c.

Roman ways passing over the ground reconnoitred; lines which they follow; where they lead to; their ramifications. Vestiges that remain of them. Nature of their materials.

Documents and historical materials existing in the museums and the public or private libraries. Printed works, manuscripts, drawings, engravings, and sculptures, that are not generally known.

Military Events.—Summary of the remarkable military events of which the ground has been the theatre, such as battles, combats, sieges, &c. Circumstances which historians generally known should have passed over, or which lack exactitude. Sources from which the information has been extracted.

APPENDIX.

On the Representation of Ground.

DURING the preparation of this work, Colonel Scott, R.E., the Examiner in Military Drawing, delivered a lecture at Chatham on the representation of ground, and in order to remedy the evil alluded to in paragraph 25, and secure uniformity of expression from different draughtsmen, he proposed a system very likely to be introduced both at Woolwich and Sandhurst. Assuming that the horizontal style is preferable to the vertical, Colonel Scott propounds his method as follows:—

"To convey the idea of relief, it is, of course, necessary to impress on the mind of the observer that the points of the drawing, at which he is looking, represent points at different levels.

"It will seem to him a very natural arrangement that for any assumed unit of vertical distance between two points on a slope, whatever its inclination, the horizontal space between them should receive a certain fixed proportion of shade.

"He will also readily admit the idea—the whole plan of the ground being covered with the projections of level lines running round the hills, at the assumed vertical unit apart—that the shade is diffused over the wide bases of the gentler slopes, and concentrated on the narrower bases of the steep inclines, corresponding to such unit.

"It will not appear a very forced arrangement if he is told that he is to suppose the shading to be laid on in lines at sensible distances apart, in the direction of the projections of imaginary level lines running round the hill, sometimes in numerous fine lines, and sometimes in what may be considered groups of fine lines drawn touching each other, so as to form one or more thicker ones, according to the slope of the ground.

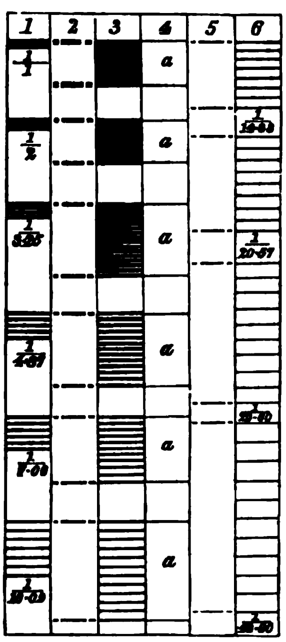
"He will, indeed, almost anticipate the last idea, for whatever the reason, the eye readily enables him to conceive that the thicker lines represent the steeper slopes, and that so vividly, that it would be very difficult to dispel the idea when once formed. This is fortunate for the success of such hill shading as I am advocating, for since a considerable number of lines are required to express the minor undulations of gentle slopes falling between two contours, and it would be impossible to draw the same number, per vertical unit, on the projections of

steep slopes, there is nothing left to us but to run the lines together for such slopes, either indiscriminately, or so as to form thicker lines with intervals between them. Now, it cannot be doubted that the most pleasing and easiest way of arranging them will be in lines having a thickness proportioned to the increasing slope, the intervals between them being gradually diminished.

"This interchangeability of number and thickness in the lines employed to produce relief being granted, we may, without doing further violence to the observer's powers of imagination, arrange the scale of their change so as best to suit our requirements.

"A slight variation is made in the thickness of the lines for the steeper slopes according to the scale of the plan, for the obvious reason that the detail of a plan on a small scale will not bear so forcible a shading as can be applied, without destroying the legibility of the detail, on a large scale.

"The scale employed in assisting the draughtsman to estimate the number and thickness of strokes per unit for scales of $\frac{1}{2500}$, $\frac{1}{5000}$ and $\frac{1}{10000}$, is shown in the diagram, and little need be said in explanation of its use. The draughtsman must, of course, take care not to give his plan a ridgy appearance, by a servile adhesion to the equi-distance of the lines on the scale, when the form of the ground requires that the space between the strokes and their force should be varied; and he must also, between two diverging contours, be careful to change the number of his strokes, without producing a harsh effect. The dotted lines should be penned in as the shading strokes are executed, or they will stand out too harshly.



Colonel Scott's scale of shade for scales $\frac{1}{2500}$, $\frac{1}{5000}$, $\frac{1}{10000}$.*

"Nothing need be said either, beyond the information given in the following tables, of the system on which the number and thickness of these lines have been graduated. The object has been simply to make the weakness inherent in the means of representing relief least felt in the representation of those slopes which are of most importance to the tactical movements of armies.

"It may be objected—and I know it will be objected—to the general employment of such a scale for giving relief, that it requires too much care and attention to be of service in

---

* In columns 1 and 6 are given the number and thickness of the strokes to be used per vertical unit for the slopes named below them, reckoning from axis to axis of the upper and lower strokes in each case. In 2 and 5 are given the horizontal distances at which the contours for the said slopes are to be shown in dots. In 3 and 6 are given the scale of shade that results from the above arrangement for the slopes named. In 4 the spaces $a \ldots . a$ are to be cut out in using the scale, so that column 3 may be applied to the sketch sheet.

ordinary field sketching; but to my mind, it hardly needs proof that if draughtsmen are educated to draw with reference to one scale, their early progress will not be retarded; and that when obliged to make rapid sketches, their work will more nearly approximate to one universal language than if they worked, each in his own fashion. A schoolboy is not retarded in his progress in writing by the copy-slips put before him; and whereas, if he is, as he grows older, free to depart from the forms of letters he was taught, he soon runs into an illegible scrawl which becomes worse and worse with practice; he will, if he adopts the profession of a clerk—whilst he loses little or nothing in celerity—always form his letters, however rapidly he writes, after the perfect type he was first taught.

"The scale for shading plans with the pen given in the following tables has been drawn up in accordance with these views, and will not be found materially to differ from that which a good draughtsman, in the horizontal style, employs in hill shading.

TABLE, *showing the Number of Strokes required for different Slopes.*

1	2	3	4
Number of strokes required per vertical unit for the scale employed.*	Approximate slopes for which the number of strokes, shown in column 1, are to be employed.	Approximate angle of inclination of the slope shown in column 2.	REMARKS.
1	$\frac{1}{1}$	45°	The slopes given in column 2 are thus obtained: commencing with the slope $\frac{1}{1}$, the denominators of the fractions representing the other slopes are the approximate numbers derived from the empirical formula:— Denominator $= 1{\cdot}5 + 1(\cdot 5)$ " $= 1{\cdot}5^2 + 2(\cdot 5)$ " $= 1{\cdot}5^3 + 3(\cdot 5)$ " $= 1{\cdot}5^4 + 4(\cdot 5)$ " . . . . . " $= 1{\cdot}5^n + n(\cdot 5)$
2	$\frac{1}{2}$	$26\frac{1}{2}$	
3	$\frac{1}{3}$	$18\frac{1}{2}$	
4	$\frac{1}{5}$	$11\frac{1}{4}$	
5	$\frac{1}{7}$	$8\frac{1}{4}$	
6	$\frac{1}{10}$	$5\frac{3}{4}$	
7	$\frac{1}{14}$	4	
8	$\frac{1}{21}$	$2\frac{3}{4}$	
9	$\frac{1}{30}$	2	
10	$\frac{1}{40}$	$1\frac{1}{4}$	

* The vertical unit here referred to is the same as the vertical distances at which the chain dotted contours are to be shown below 5°. (*See* next Table.)

work; it cannot vitiate the general form of the hill which the contours trace out; and these, by the definite language which they speak, check at once very serious inaccuracies.

"This, then, is the system which I have to propose; it makes no pretension to originality of conception, or to be supported by any learned argument on mathematical or natural representation. The chief aim has been to adopt the simplest forms of conventionality consistent with that degree of naturalness of representation which is necessary to impart the idea of relief, without strain on the imagination and memory of the observer; consistent also with giving aid to the sketcher in his labours, and enabling him best to delineate those gradations of slope which it is of most importance to a general, in command of an army in the field, to read with some degree of accuracy."

This method has for object to secure uniformity in the representation of the same ground by different draughtsmen, and to combine accuracy with pictorial effect. The accuracy is secured by the chain-dotted contours, and the effect by a diapason of shade, giving a tint proportional to the inclination. Plate 40 has been drawn by Major Petley according to the diapason, but the chain-dotted contours have been omitted.

INDEX.

ERRATA.

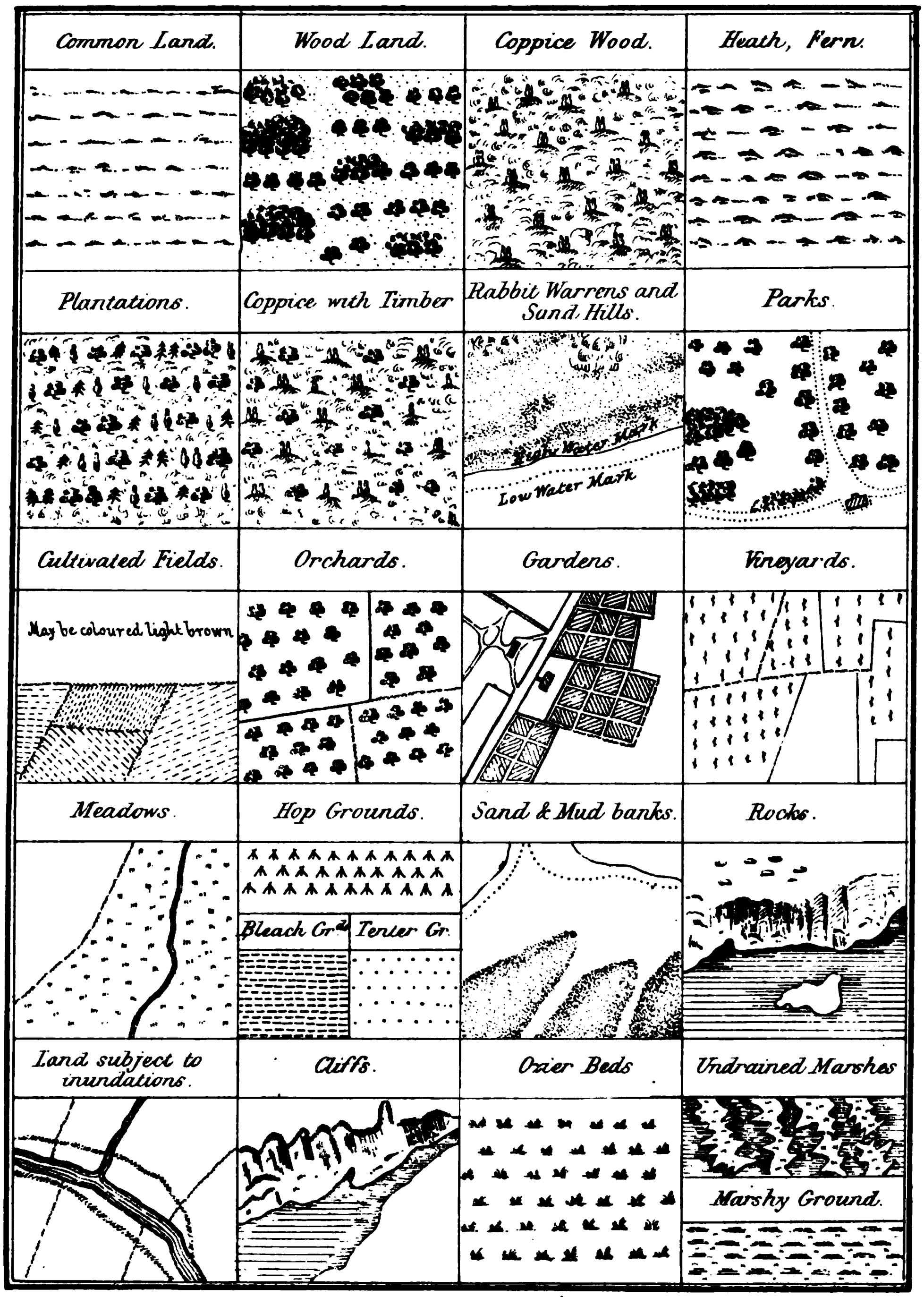
Page 15, line 7		*instead of*	a c = c b	*read*	a c = a b
18	„ 1	„	margin	„	horizon
18	„ 3	„	5 to 6	„	5 to 5
24	„ 6	„	square	„	squares
24	„ 11	„	contour	„	contours
25	„ 1	„	A C′ : A B′	„	A C : A B
28	„ 8	„	B A B	„	B A G
32	„ 6	„	perpendicular	„	perpendiculars
44	„ 2 from bottom	„	On the plan	„	On the plan construct
47	„ 2	„	X	„	x

Reference to 79, 80, &c., to 87, should be altered to 78, 79, &c., to 86

Page 63, line 3		*instead of*	a b	*read*	b x
63	„ 5 from bottom	„	plan	„	plane
64	„ 2	„	$z_, x_,$	„	$a_, x_,$
64	„ 11	„	in line the edge	„	in line; the edge
71	„ 7	„	(n − 1), D	„	(n − 1) D
71	„ 7 from bottom	„	12° − 9′	„	12° 9′
72	„ 2	„	exceed or fall short of 360°	„	exceed 360°
83	„ 4 from bottom	„	a d b c	„	a d, b c
96	„ 2	„	outline	„	outlines
100	„ 5 from bottom	„	(Euclid, p. lvi.)	„	(Euclid, lib. lvi.)
101	„ 2 from bottom	„	the less	„	the least

CONVENTIONAL SIGNS.

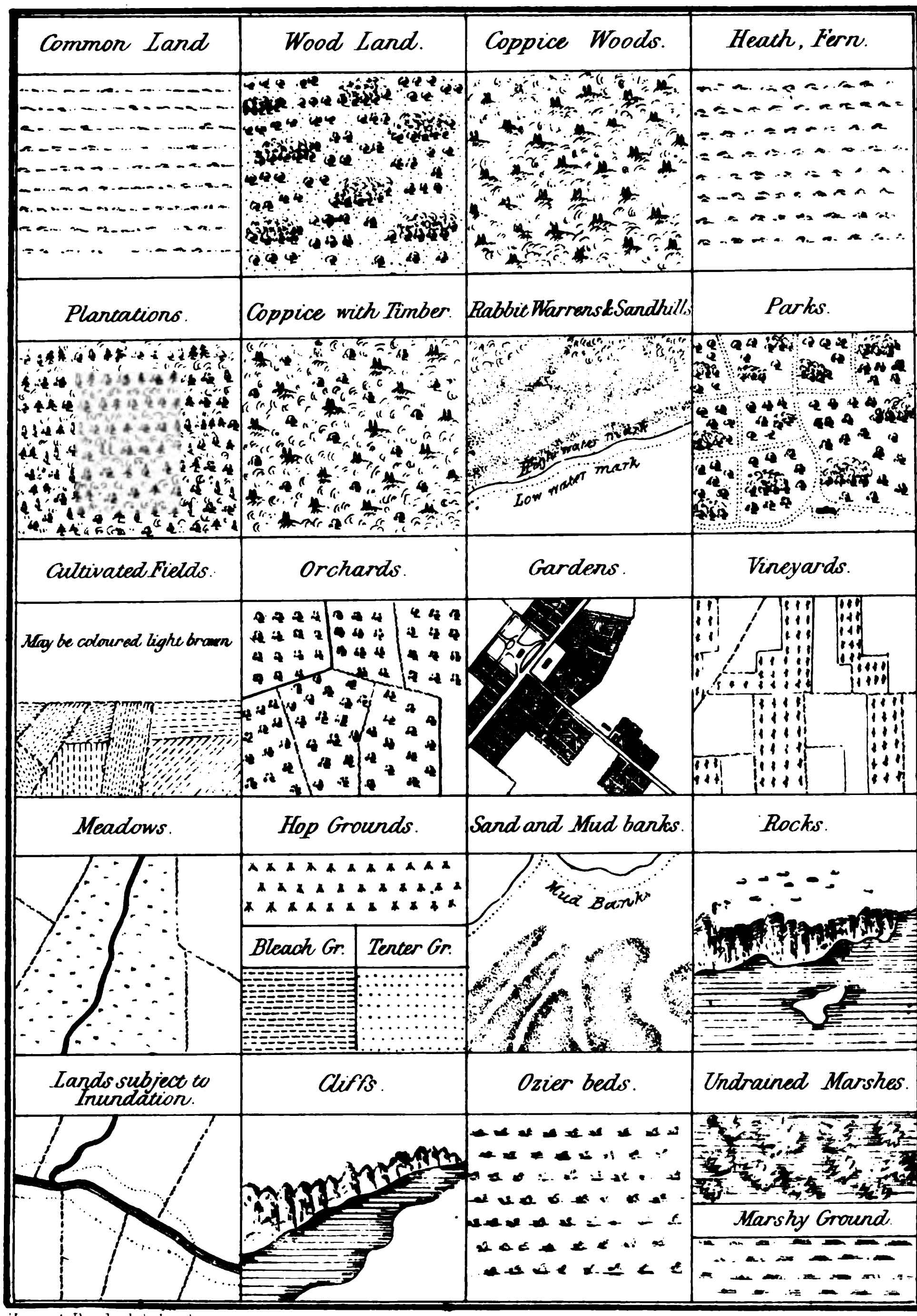
FOR THE SCALE OF 6 INCHES TO 1 MILE.



London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

CONVENTIONAL SIGNS.

FOR THE SCALE OF 3 INCHES TO 1 MILE



Vincent Brooks, lith. London

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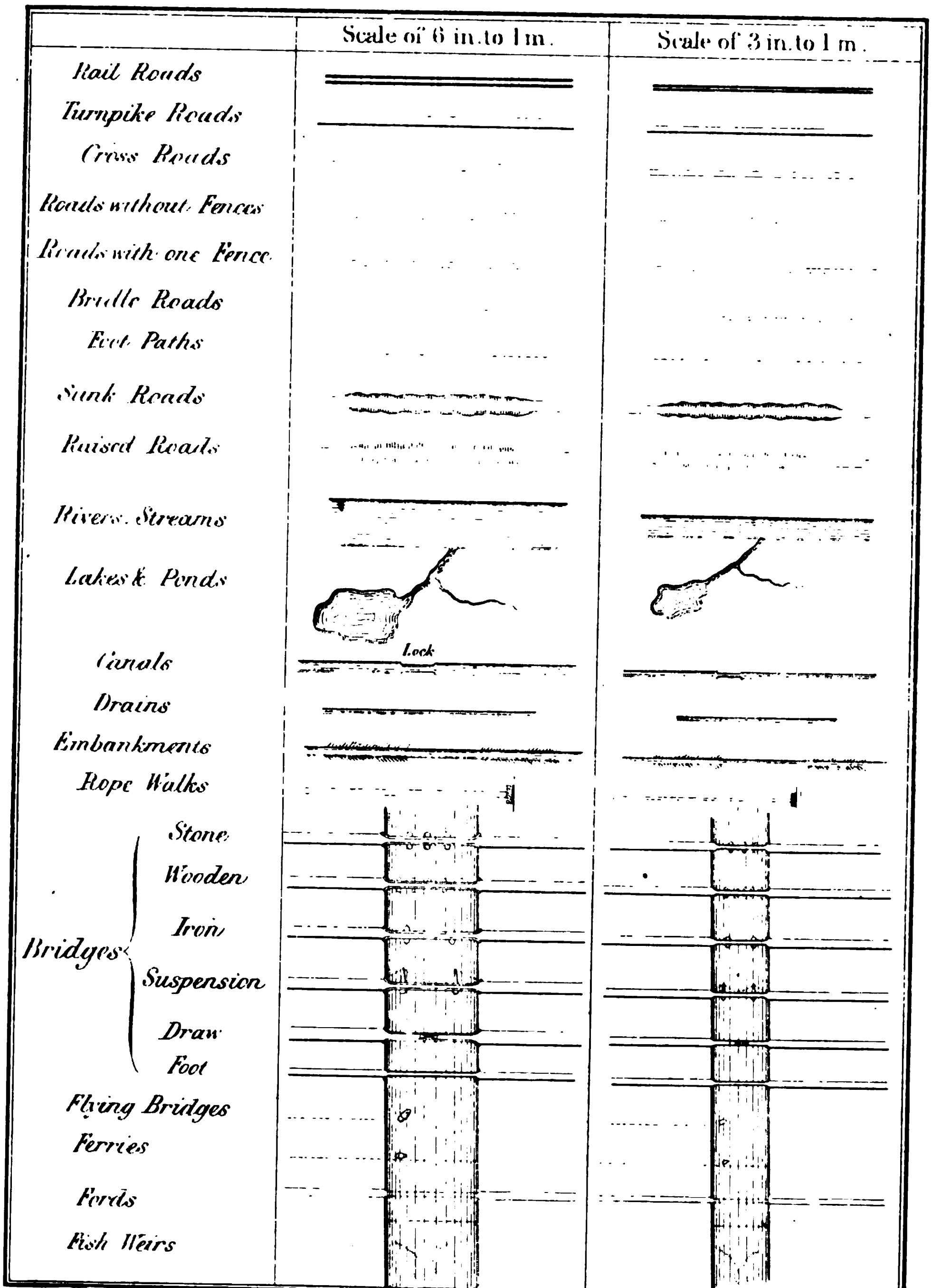
CONVENTIONAL SIGNS.



Vincent Brooks, lith. London.

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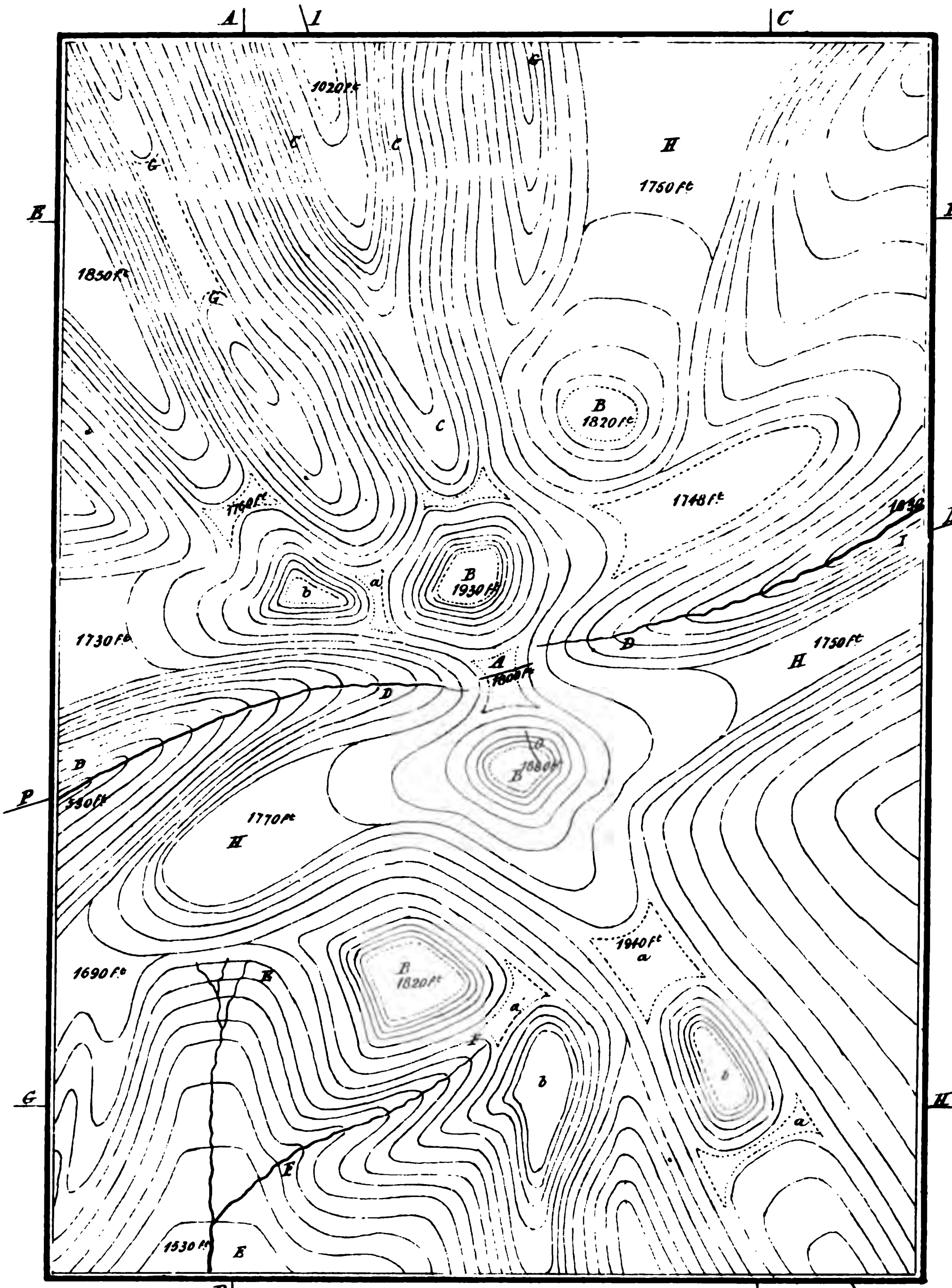
CONVENTIONAL SIGNS.

	Scale of 6 in. to 1 m.	Scale of 3 in. to 1 m.
Earthen Fences		
Walls		
Rail Fences, Palings		
Hedges		
Hedges with Trees		
Lime Kilns		
Churches		
Houses and Farms		
	(may be coloured Red)	*(do.)*
Smithies		
Stone Windmills		
Wooden do.		
Watermills		
Iron Works		
Glass do.		
Light Houses		
Telegraphs		
Mercury	☿	do.
Copper	♀	do.
Lead	♄	do.
Silver	☽	do.
Gold	☉	do.
Iron	♂	do.
Tin	♃	do.
Coal	•	do.

Vincent Brooks, lith. London.

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.



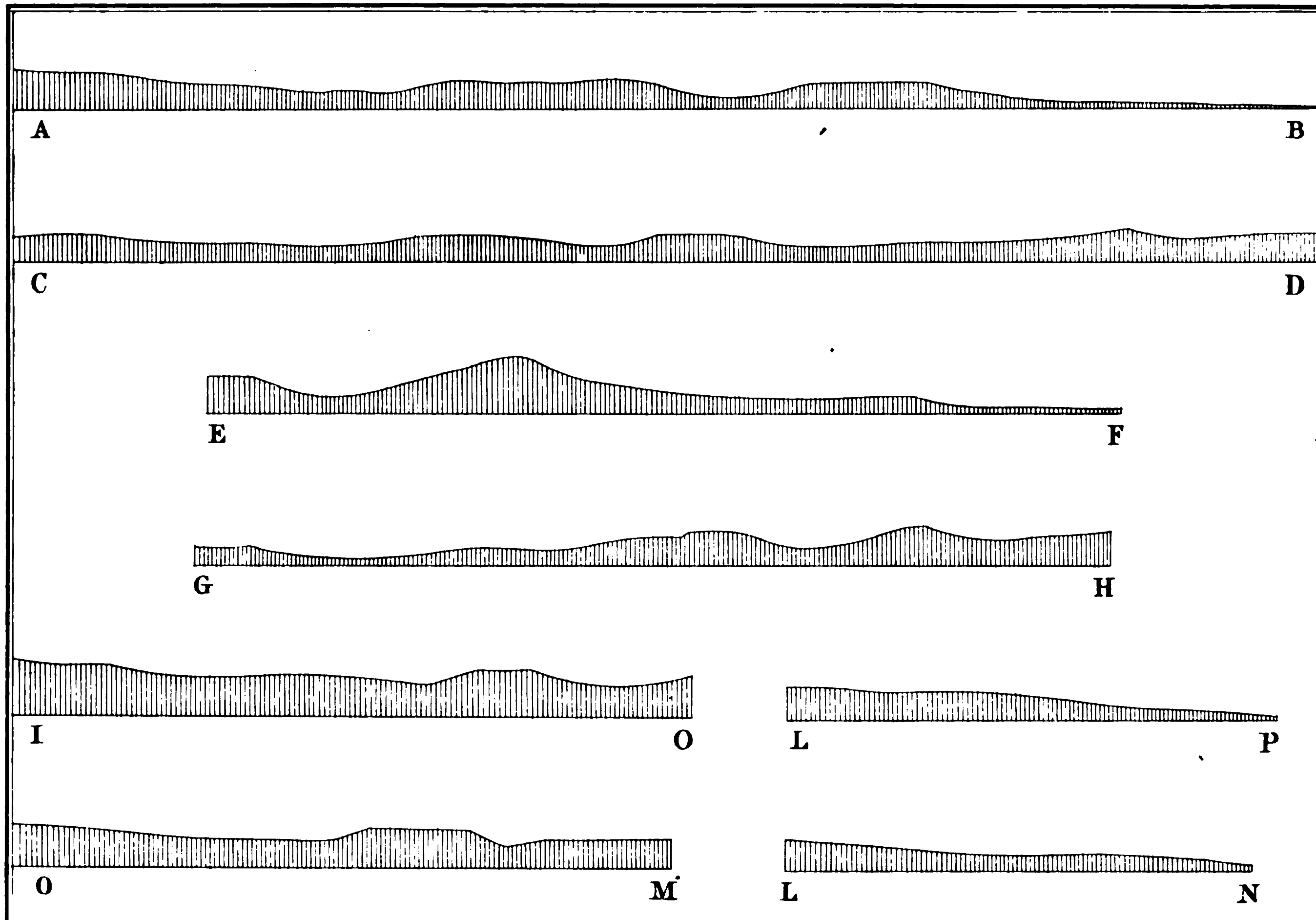
EQUIDISTANCE OF 20 FT

SCALE OF 3 INCHES TO 1 MILE

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

SECTIONS (SEE PLATE V.)

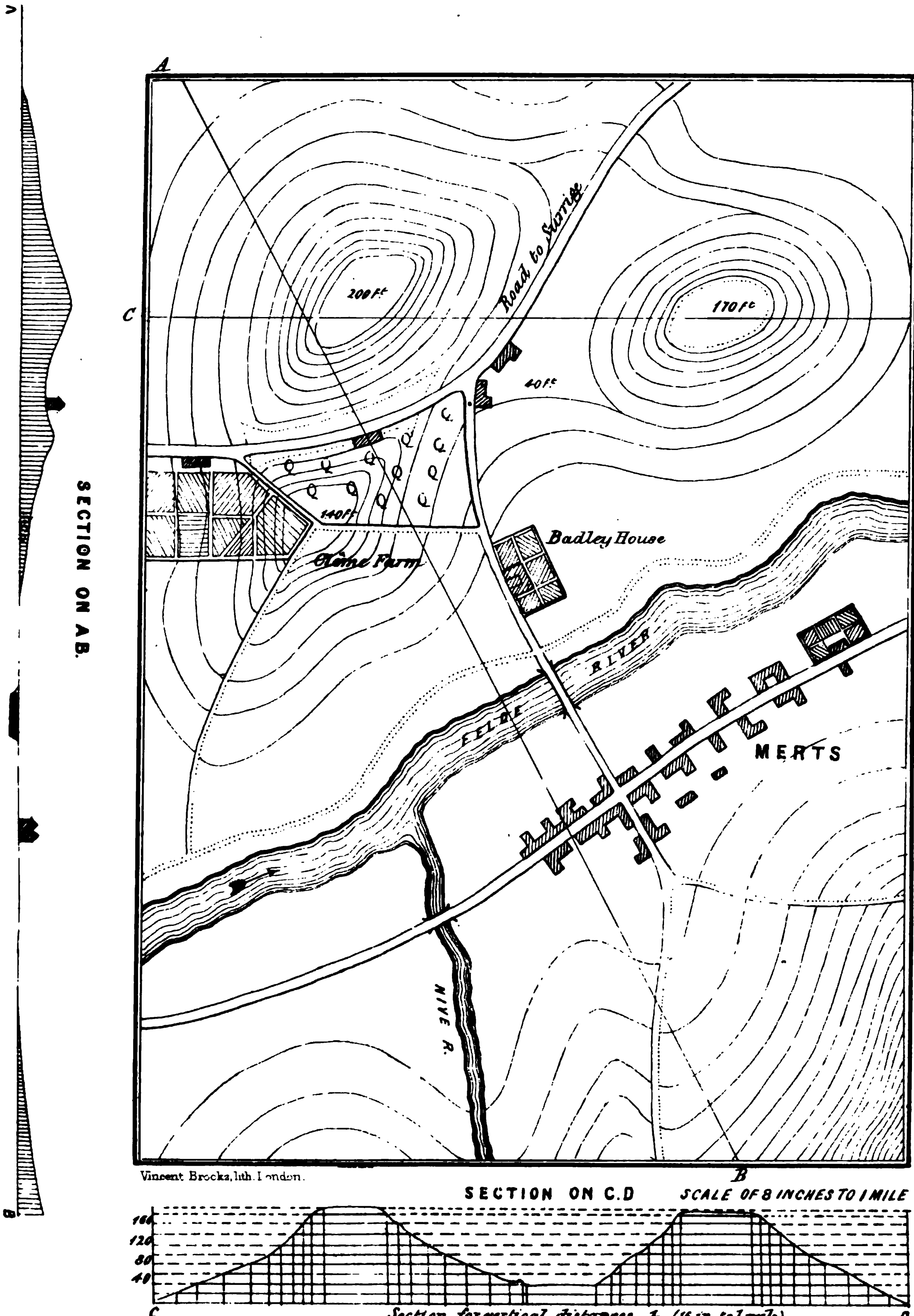
ON BASE LINES 1500 F^T. ABOVE THE SEA LEVEL.



1, SCALE OF 3 INCHES TO 1 MILE.

Vincent Brooks lith London

London Published June 1864 by Atchley & C? 106, G? Russell S? W.C.



Vincent Brooks, lith. London.

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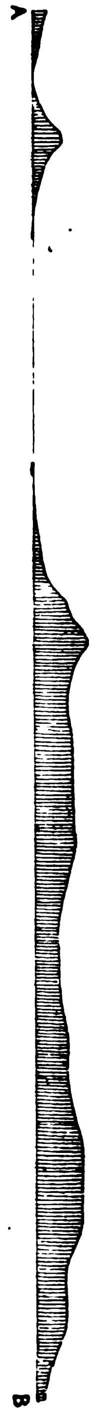
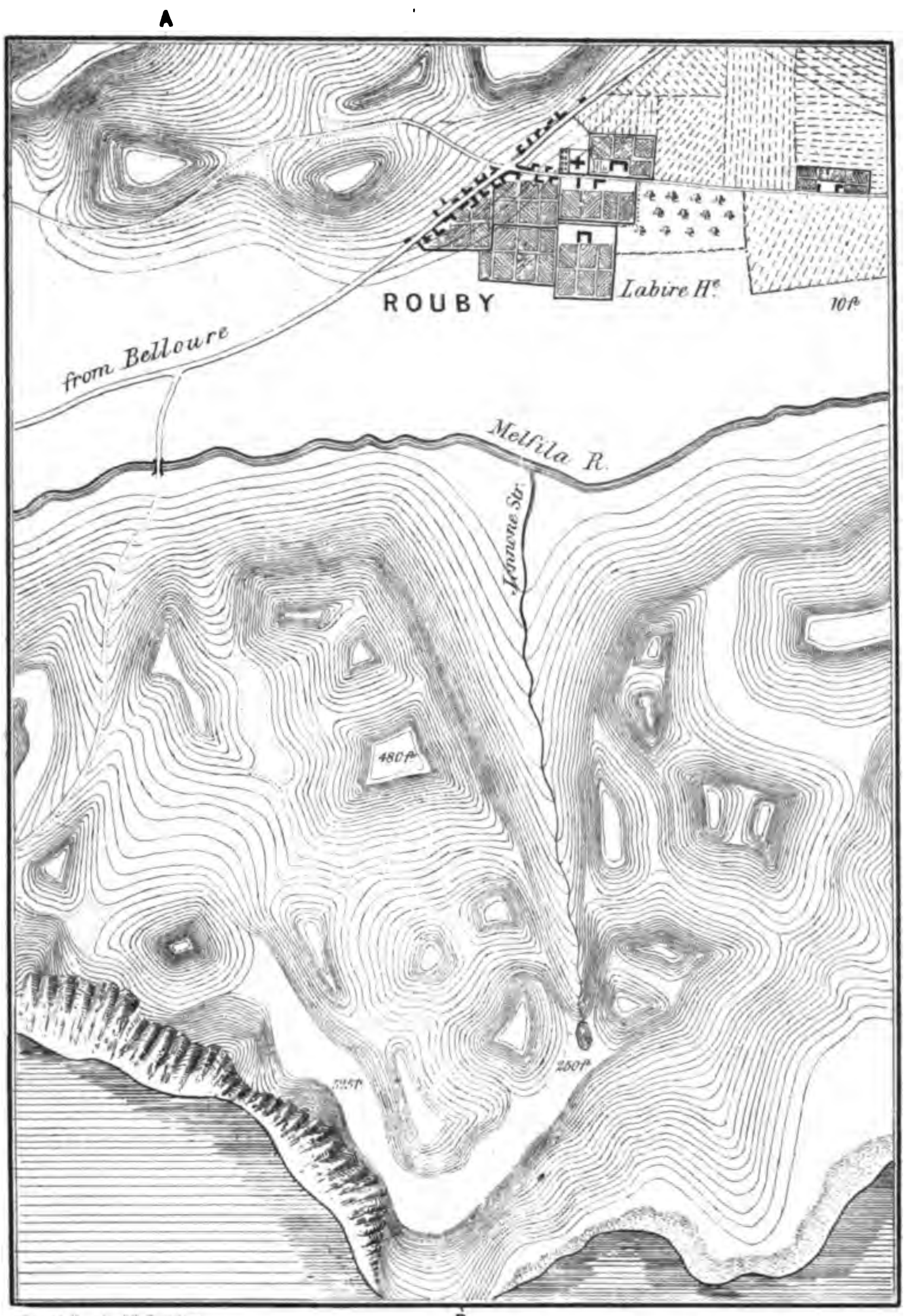
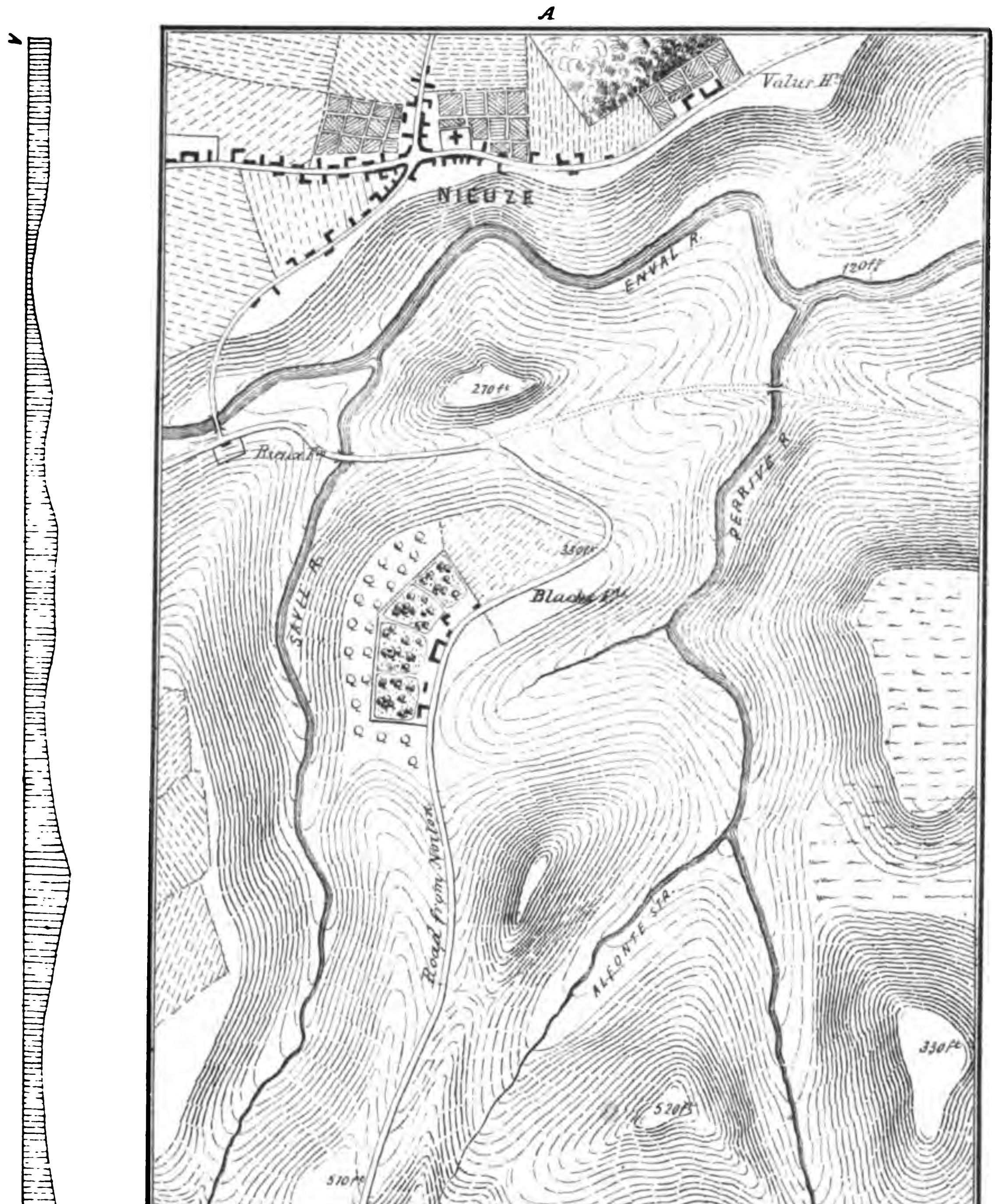


SECTION ON A B C



SCALE OF 3 INCHES TO 1 MILE

London Published June 1864 by Atchley & C° 106 G! Russell S! W.C.

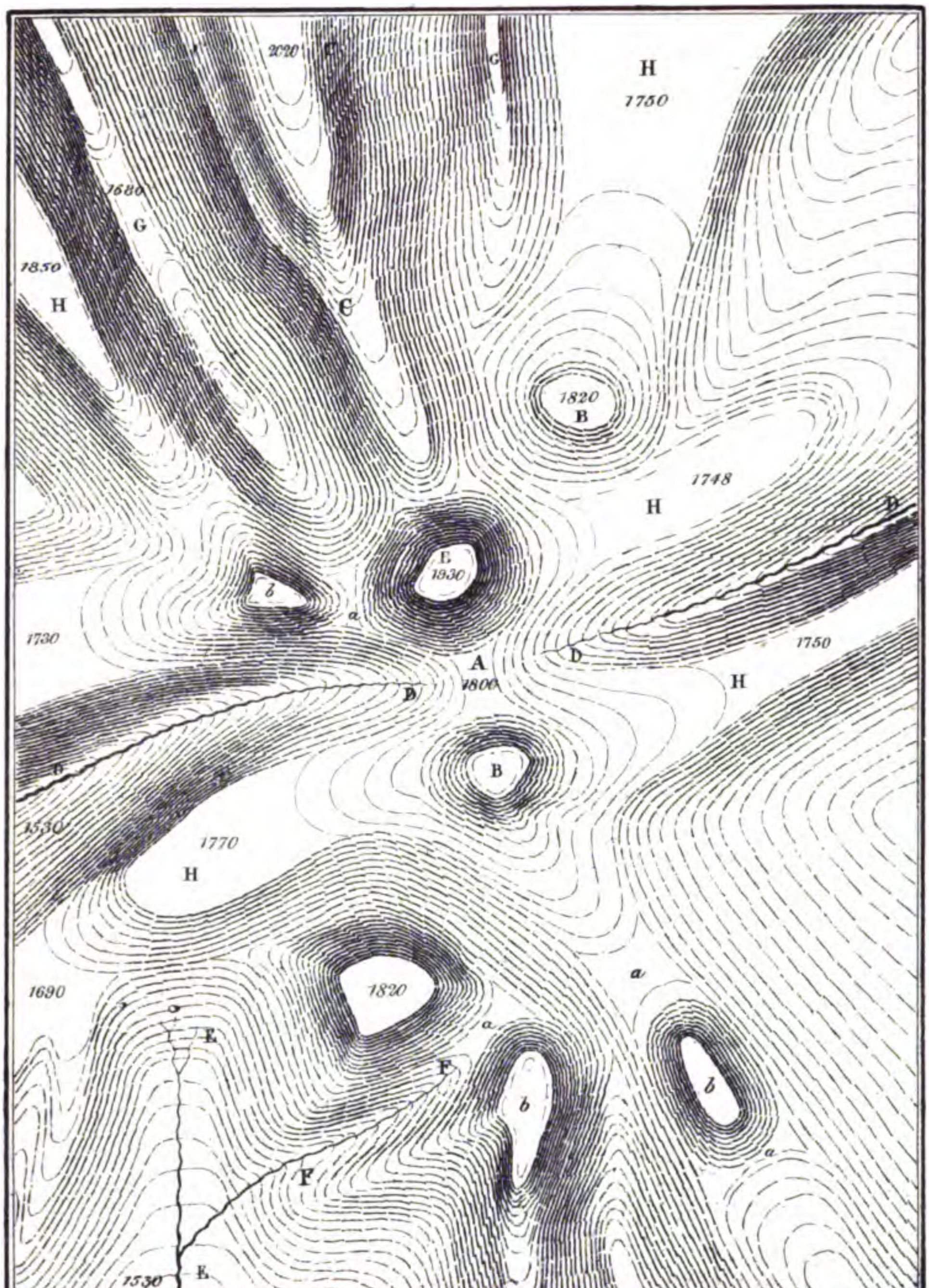


Vincent Brooks, lith. London.

SCALE OF 3 INCHES TO 1 MILE

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

PLATE X.



London Published June 1854 by

MAJOR PETLEY'S SERIES.

PLATE XI

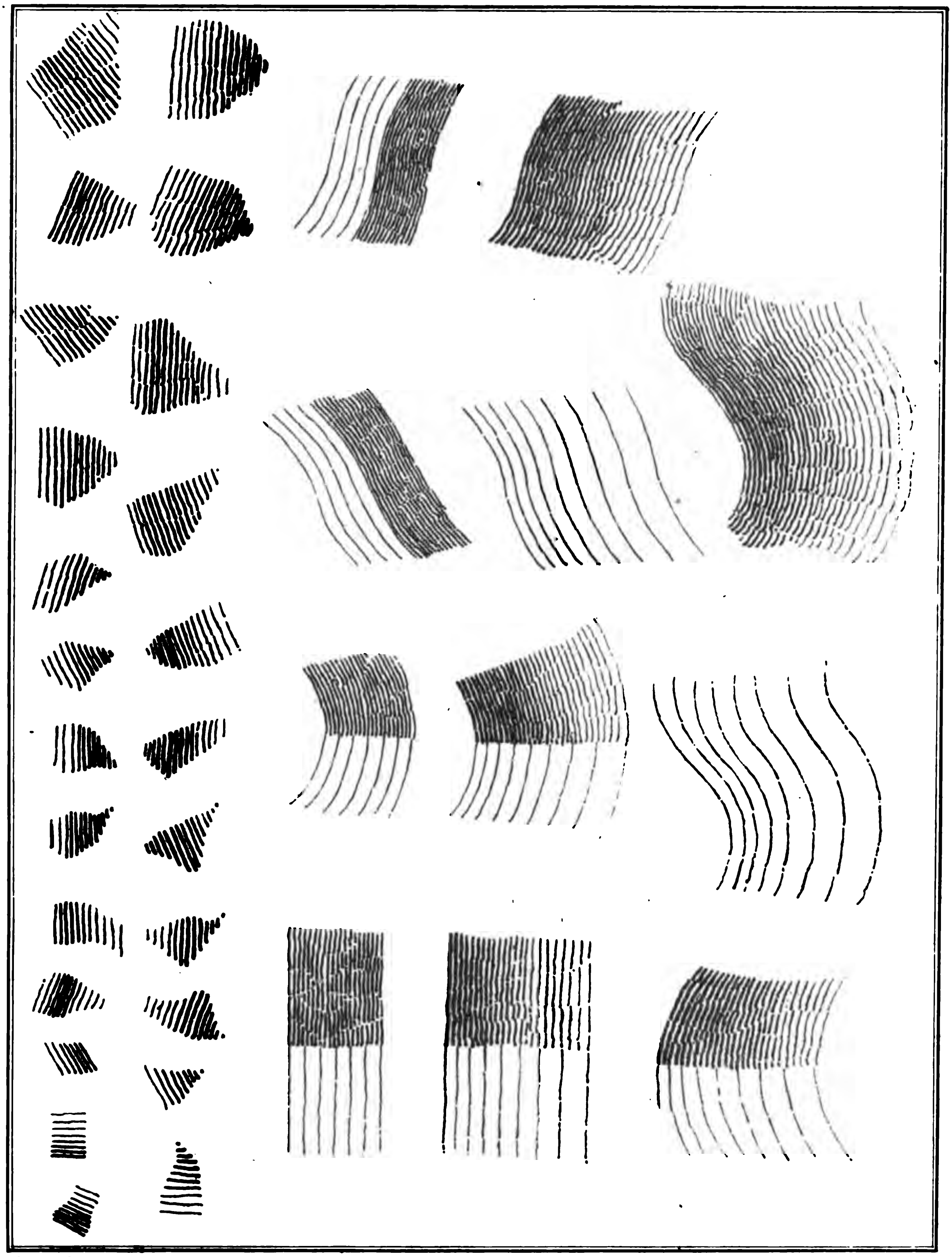


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PLATE XII.

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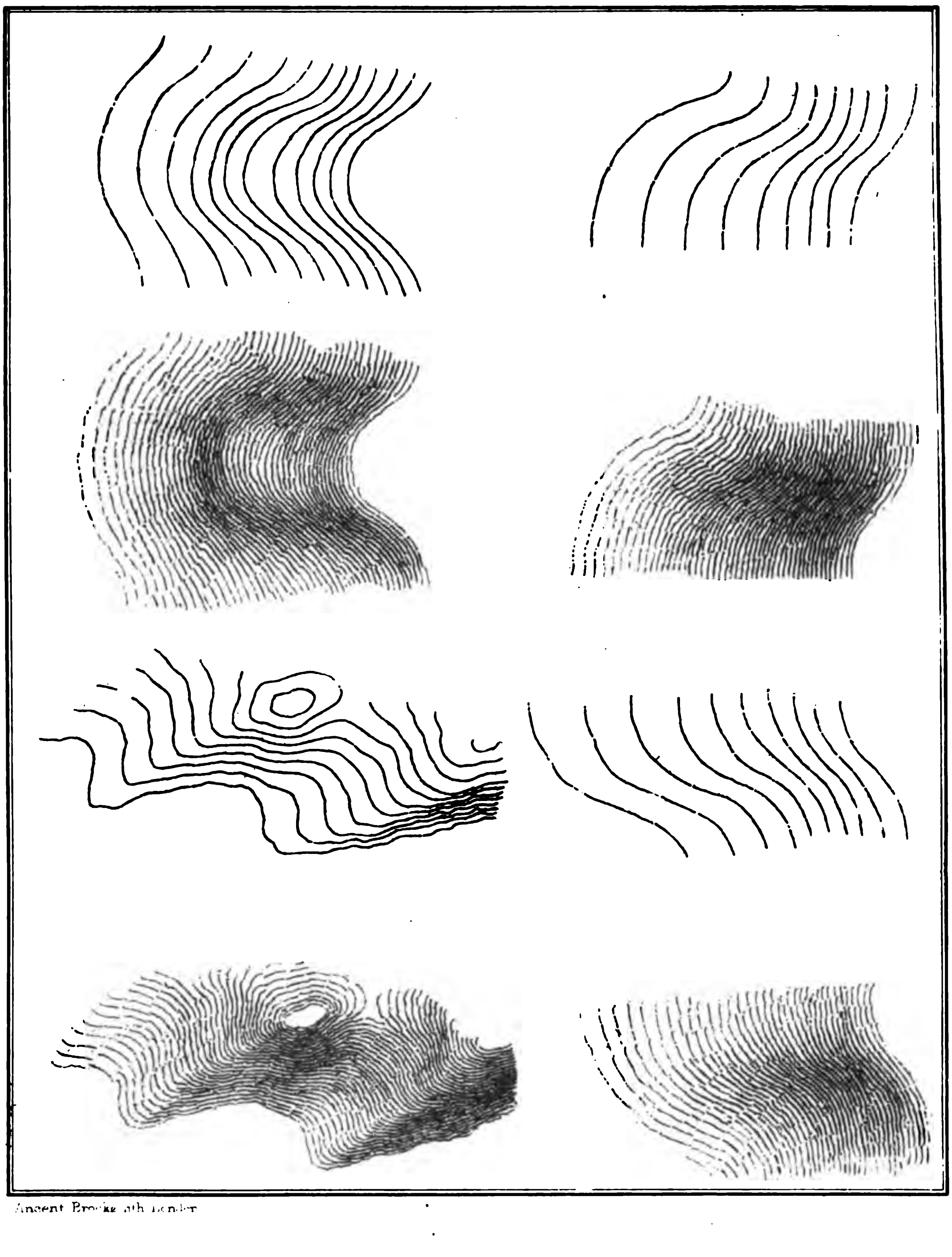
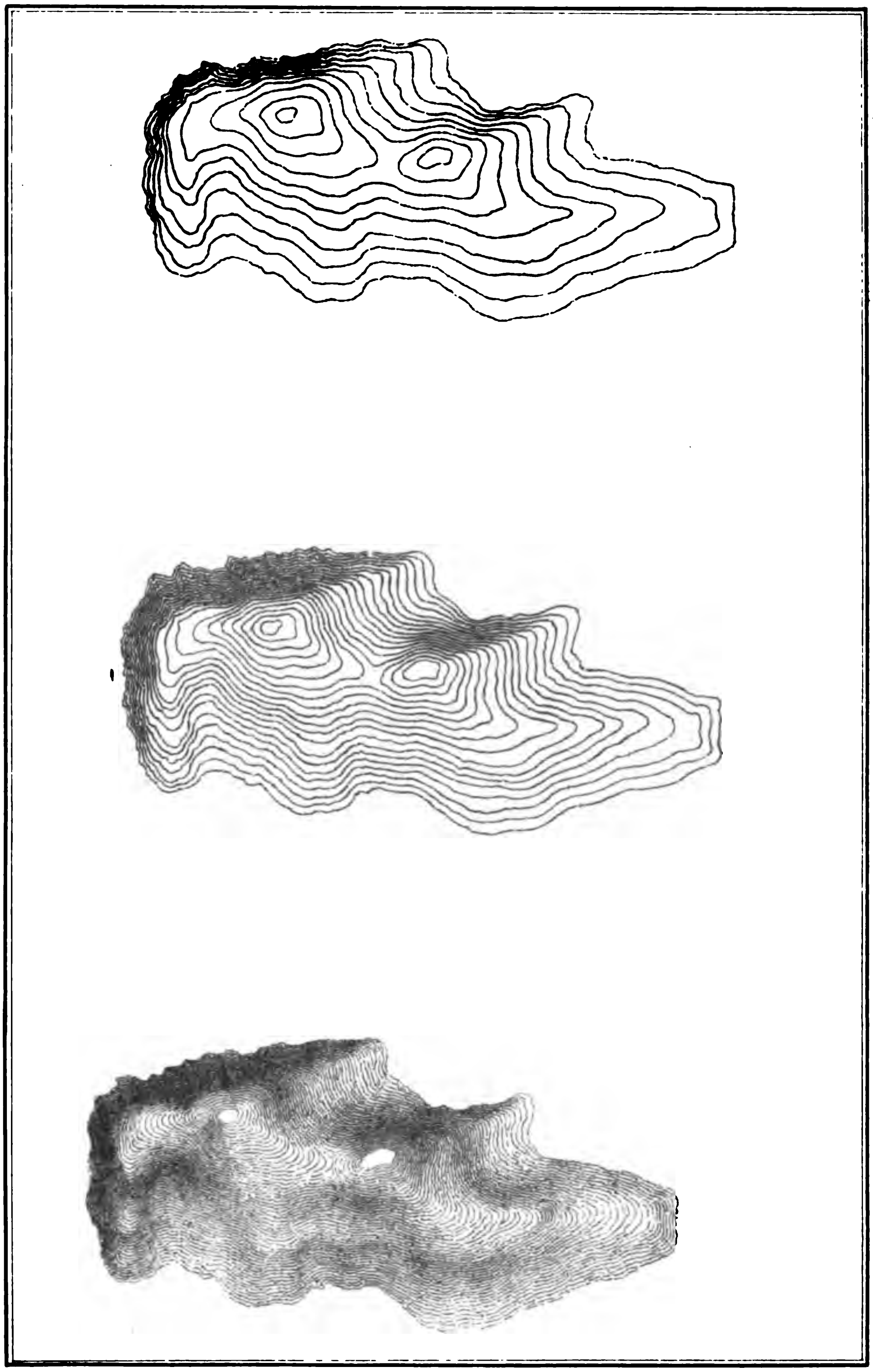


Vincent Brooks, Lith. London.

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

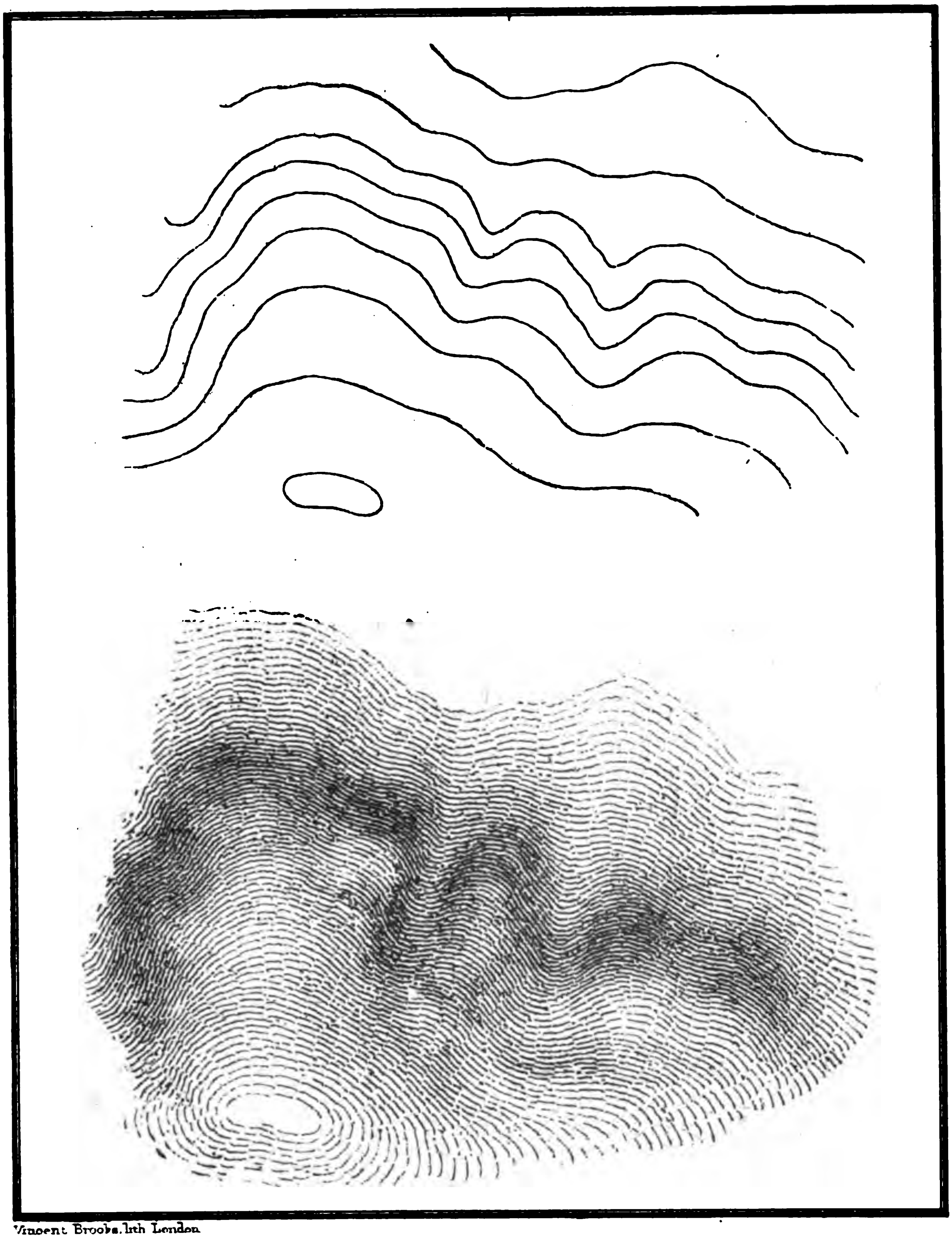
PLATE XIII.

MAJOR PETLEY'S SERIES.



Vincent Brooks, lith. London.

MAJOR PETLEY'S SERIES.



Vincent Brooks, lith London

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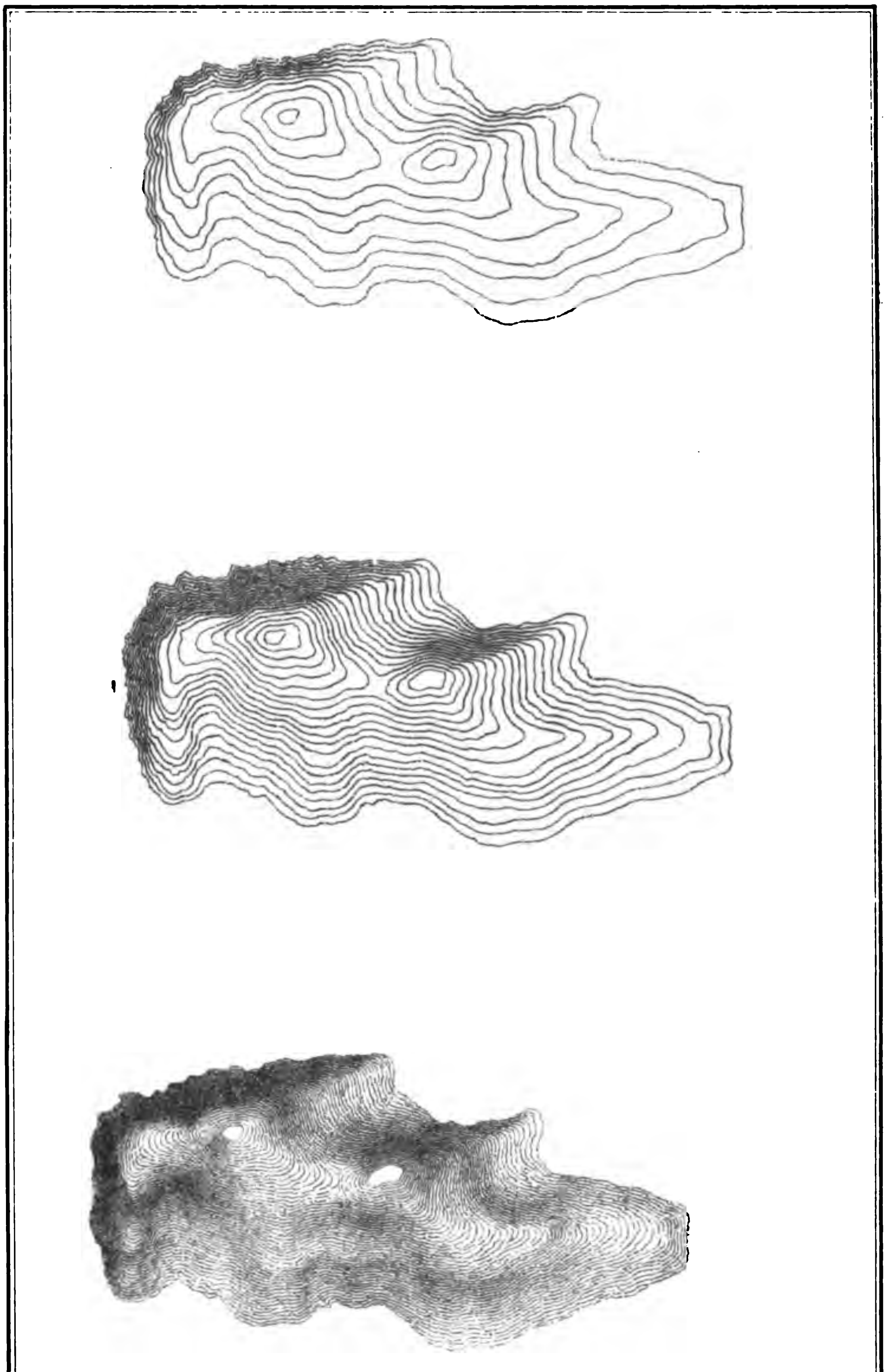
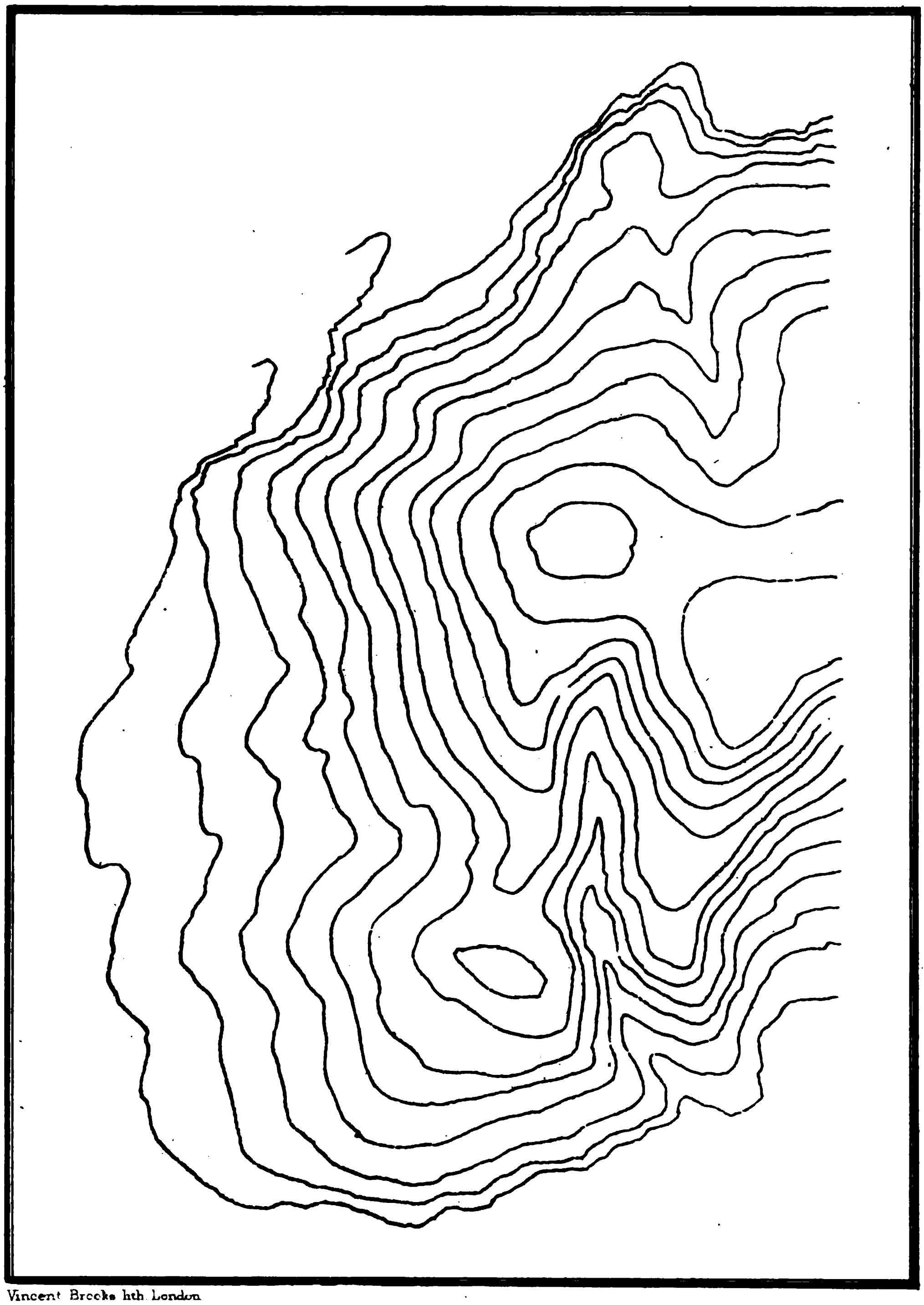
MAJOR PETLEY'S SERIES.



Vincent Brooks, lith. London

MAJOR PETLEY'S SERIES.



Vincent Brooks lith London

London Published ... [illegible]

PLATE XVI.(a.)

MAJOR PETLEY'S SERIES.

Vincent Brooks lith London.

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

A MILITARY SKETCH
BY MAJOR PETLEY.

Vincent Brooks, lith. London

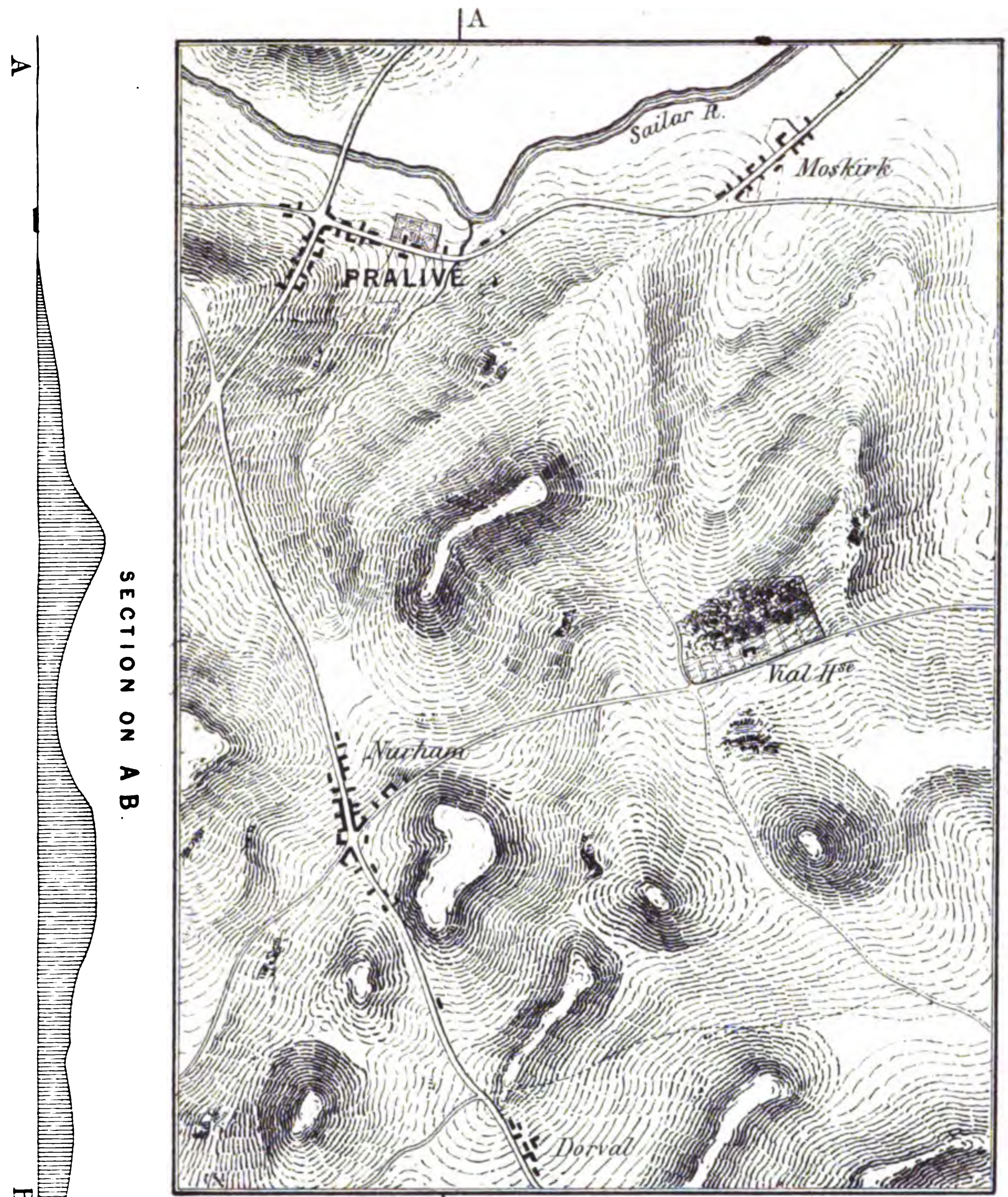
London, Published June 1864 by Atchley & Co 106 Gt Russell St W.C.

A MILITARY SKETCH

BY CAPTN RICHARDS.

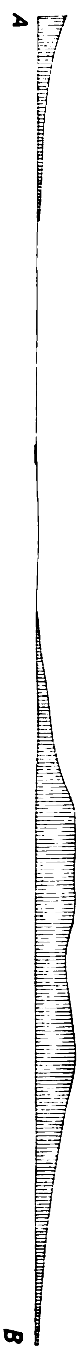
Vincent Brooks, lith. London.

London. Published June 1864 by Ashley & Co 1[illegible] Gt Russell St W.C.

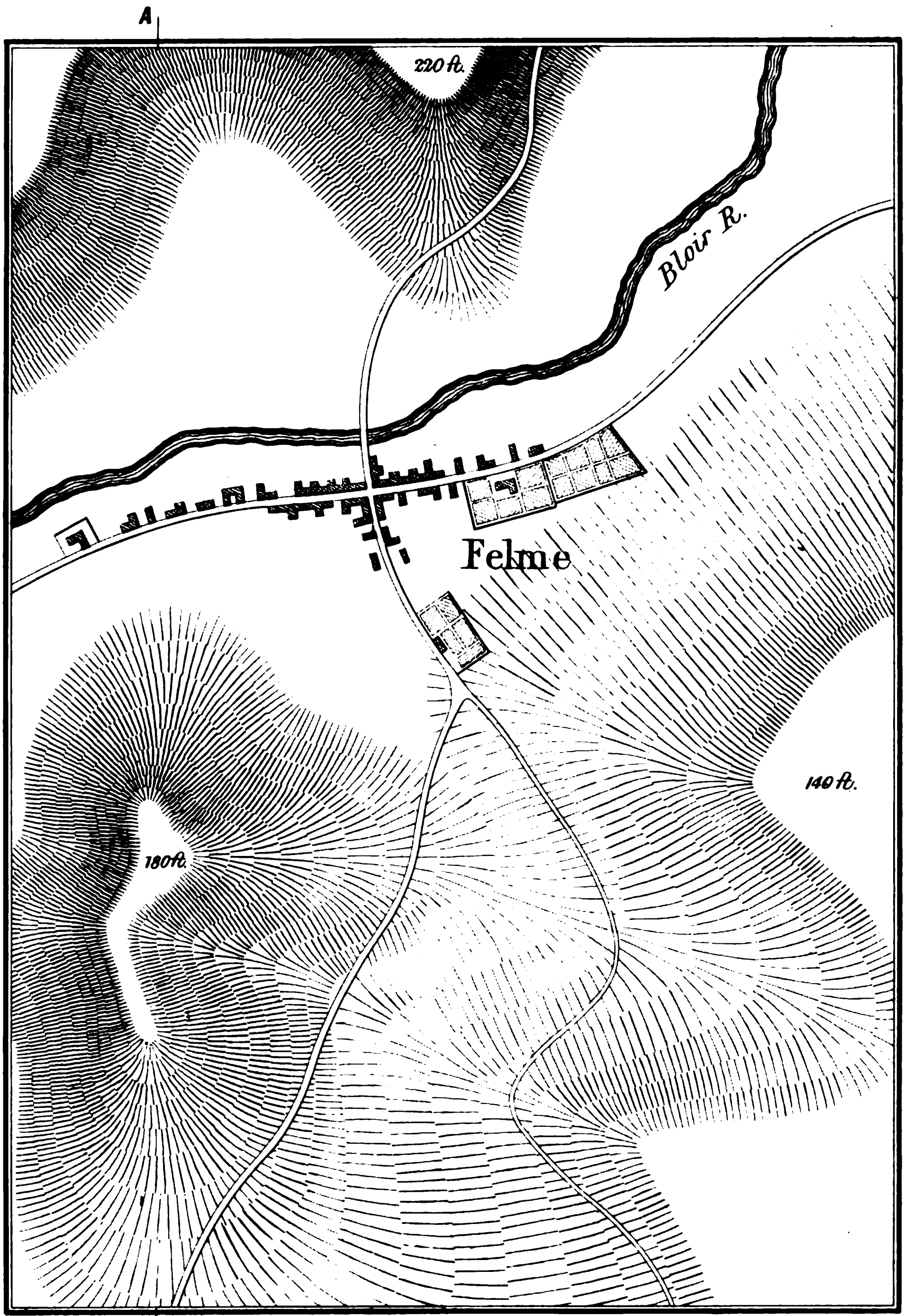


SCALE OF 3 INCHES TO 1 MILE

PLATE XX.

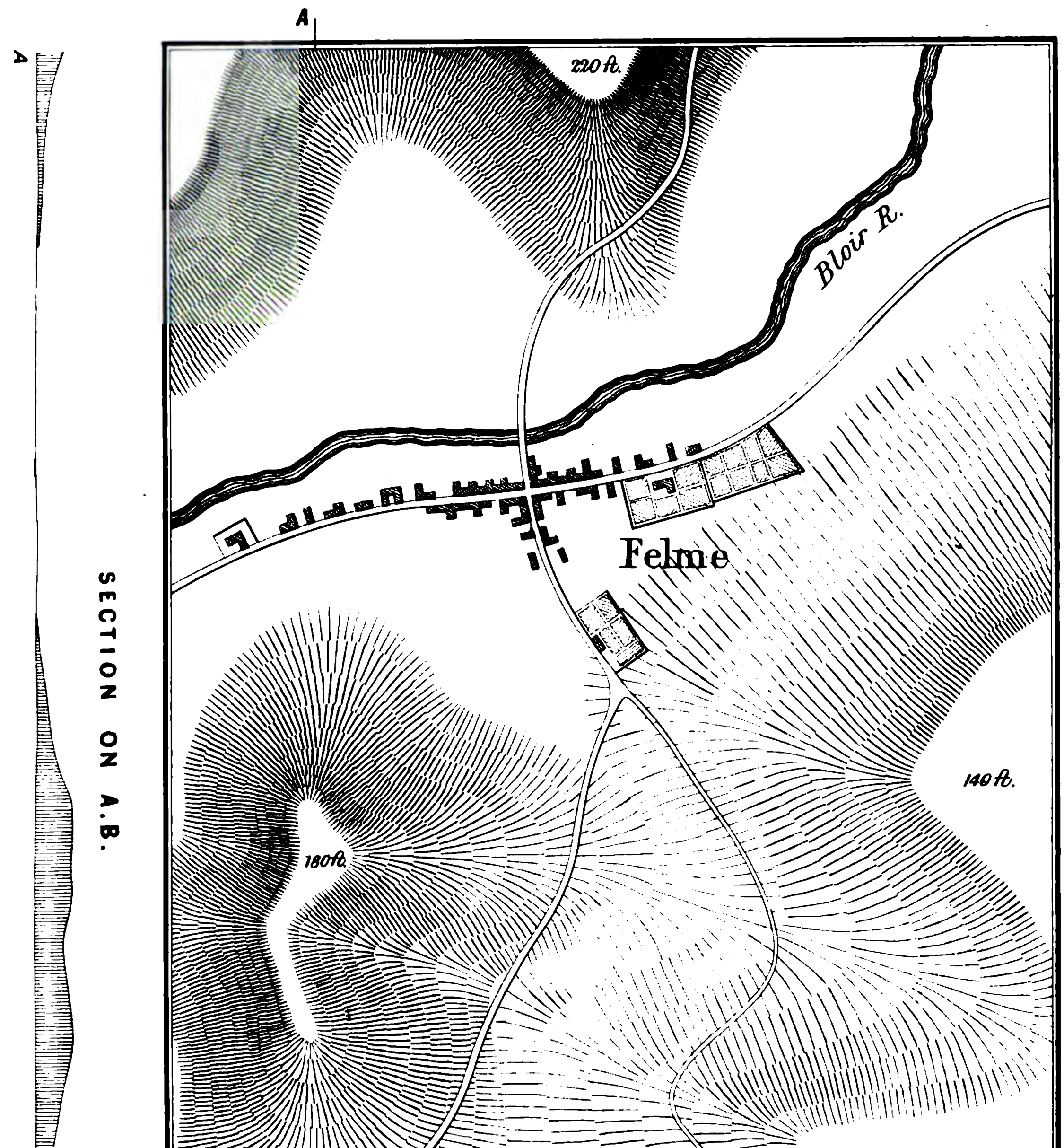


SECTION ON A.B.



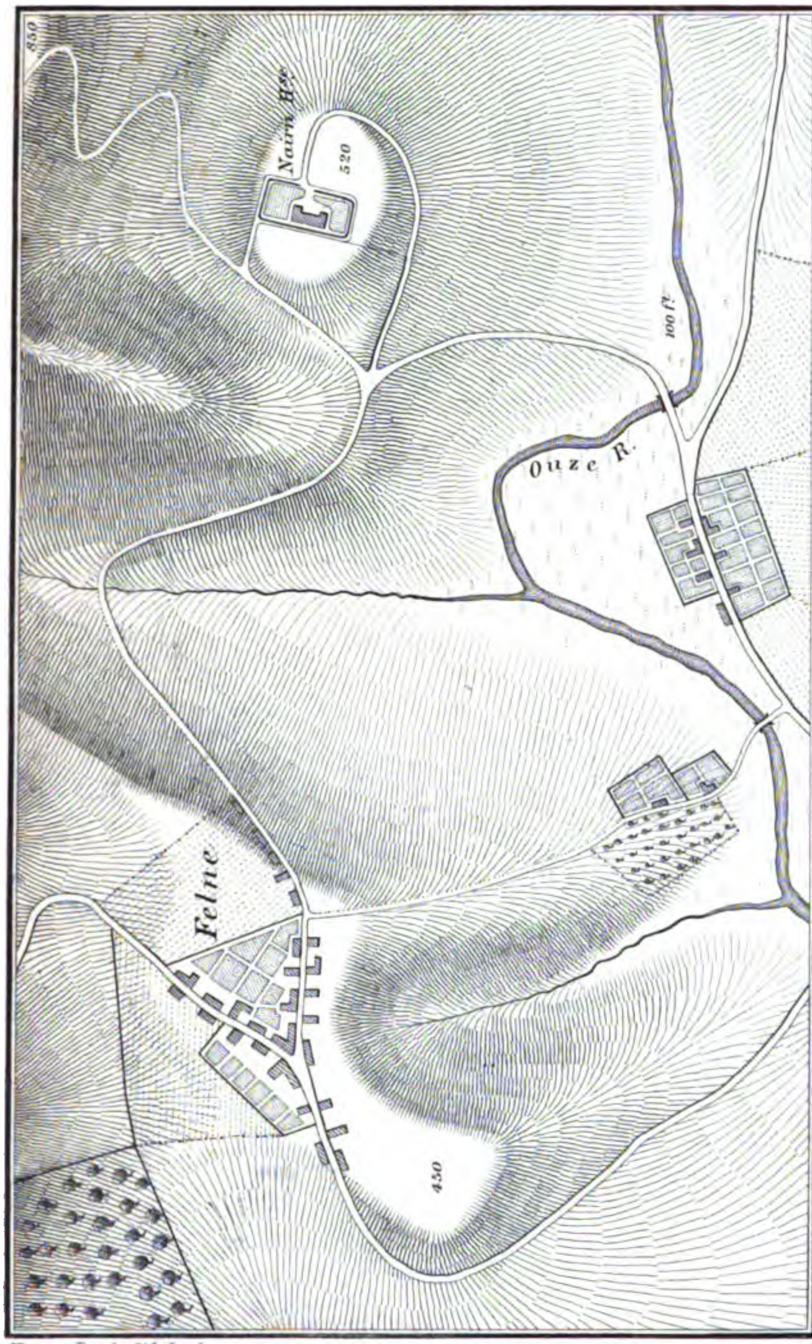
SCALE OF 6 INCHES TO 1 MILE.

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.



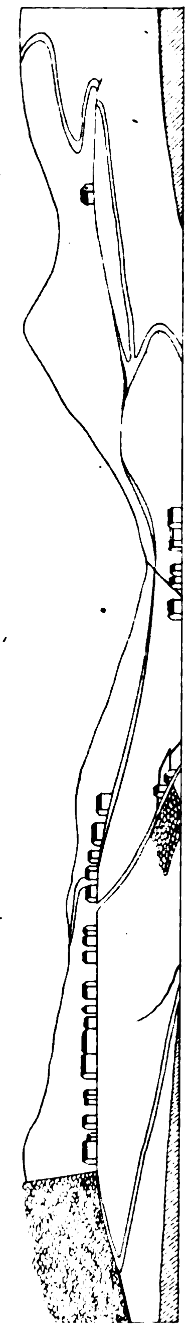
SCALE OF 6 INCHES TO 1 MILE.

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.



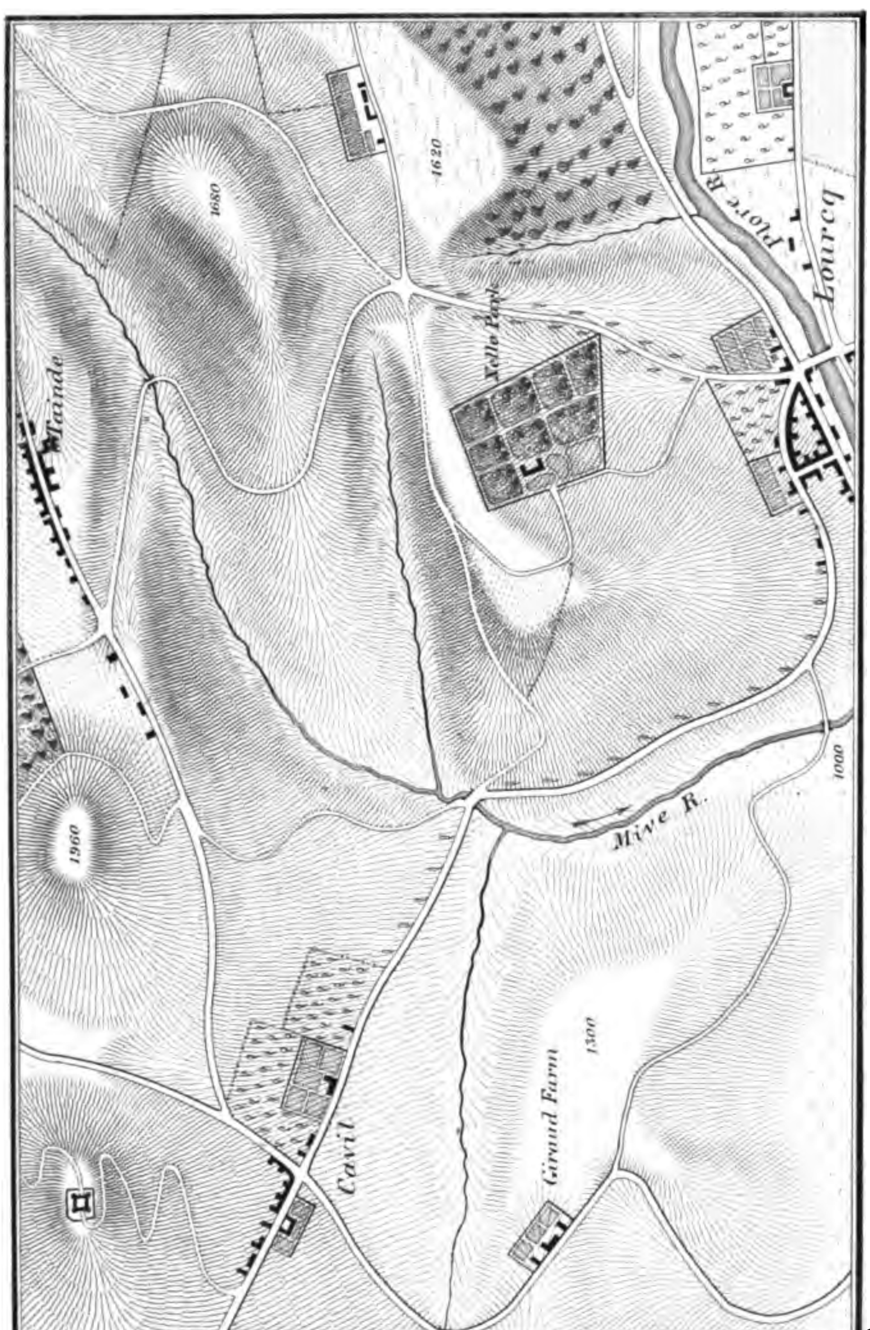
Vincent Brooks, lith London.

Scale of 6 inches to 1 mile.



Elevation on A B.

London Published June 1864, by Atchley & Co 106, Gt Russell St W.C.

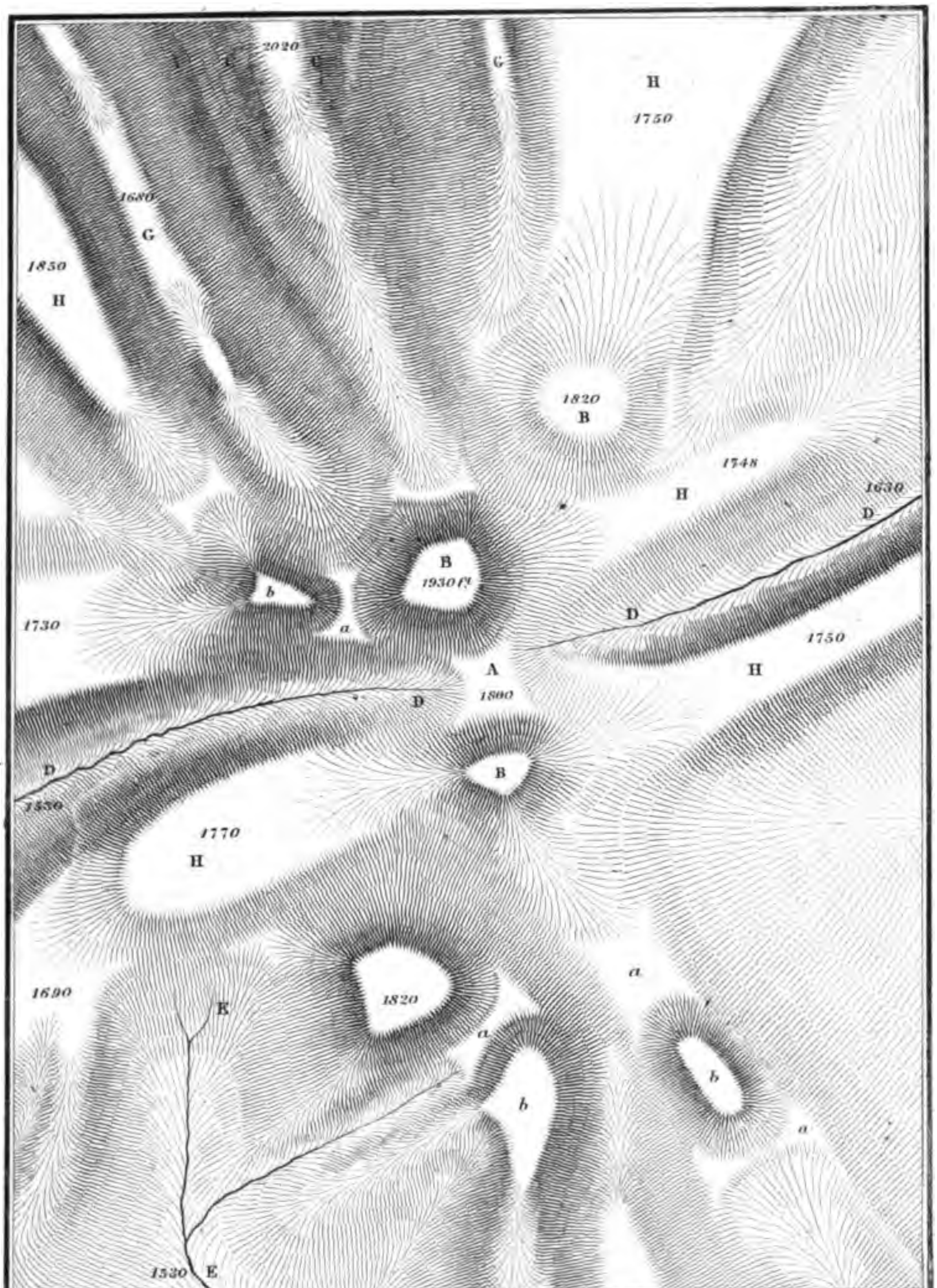


Scale of 3 inches to 1 mile.

Elevation on A B.

Vincent Brooks, lith London.

London: Published June 1864, by Atchley & Co. 106, Gt Russell St W.C.



Vincent Brooks, lith. London.

Scale of 3 inches to 1 mile.

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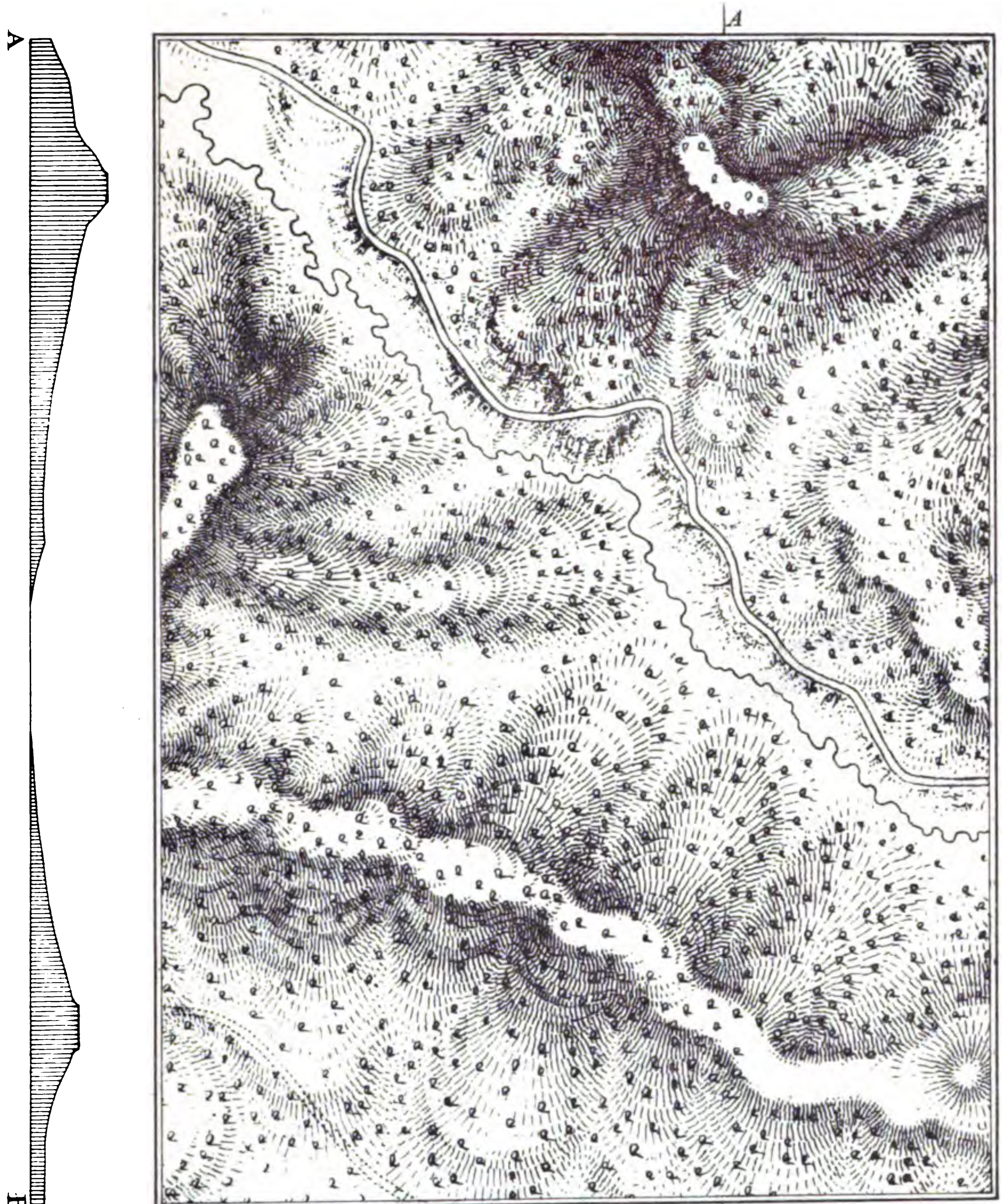
FROM THE QUARTER-MASTER-GENERAL'S
SURVEY IN THE CRIMEA.

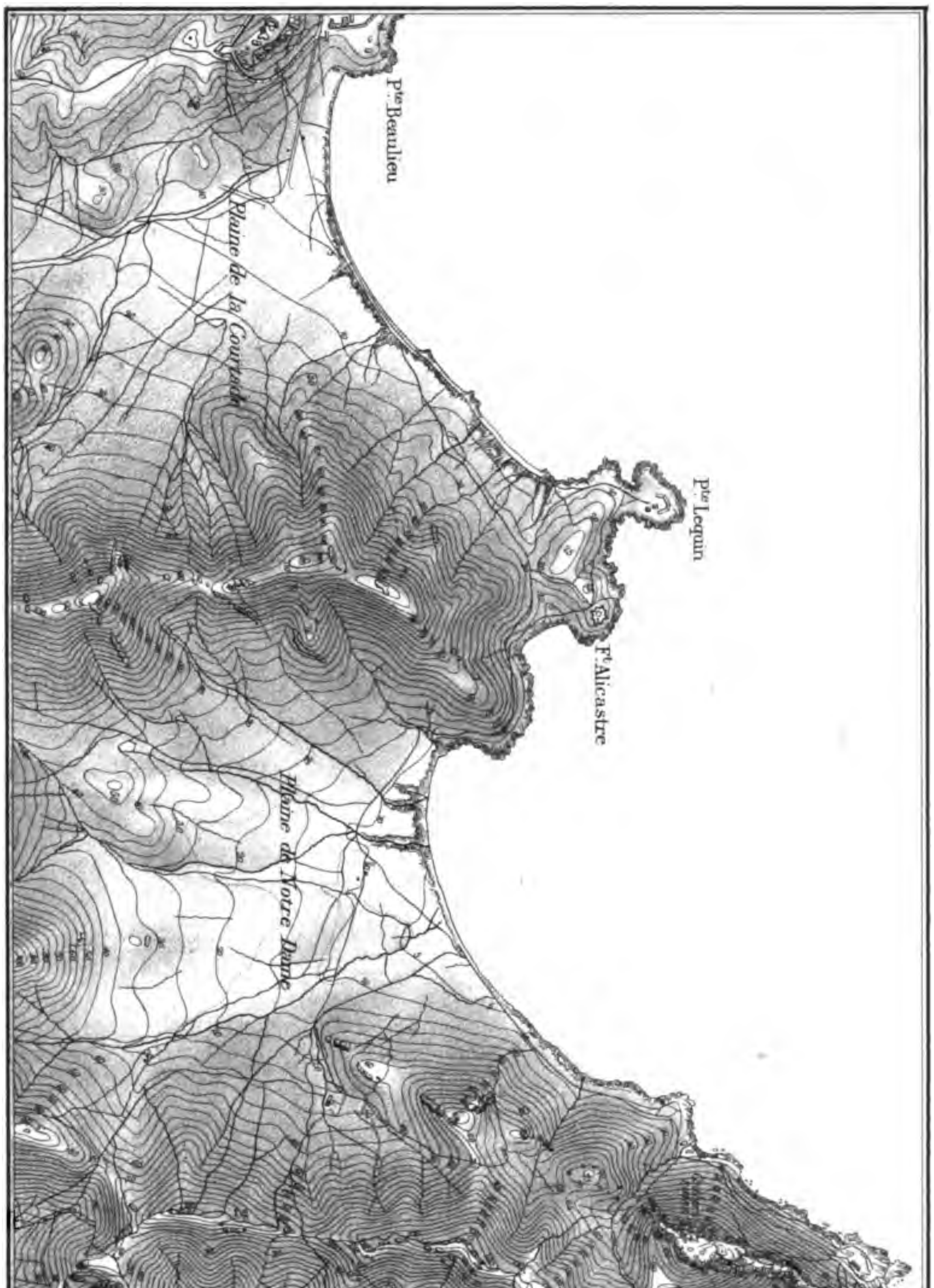


Vincent Brooks lith. London

SCALE OF 4 INCHES TO 1 MILE.

London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

FROM PROFESSOR BARDIN'S SERIES.

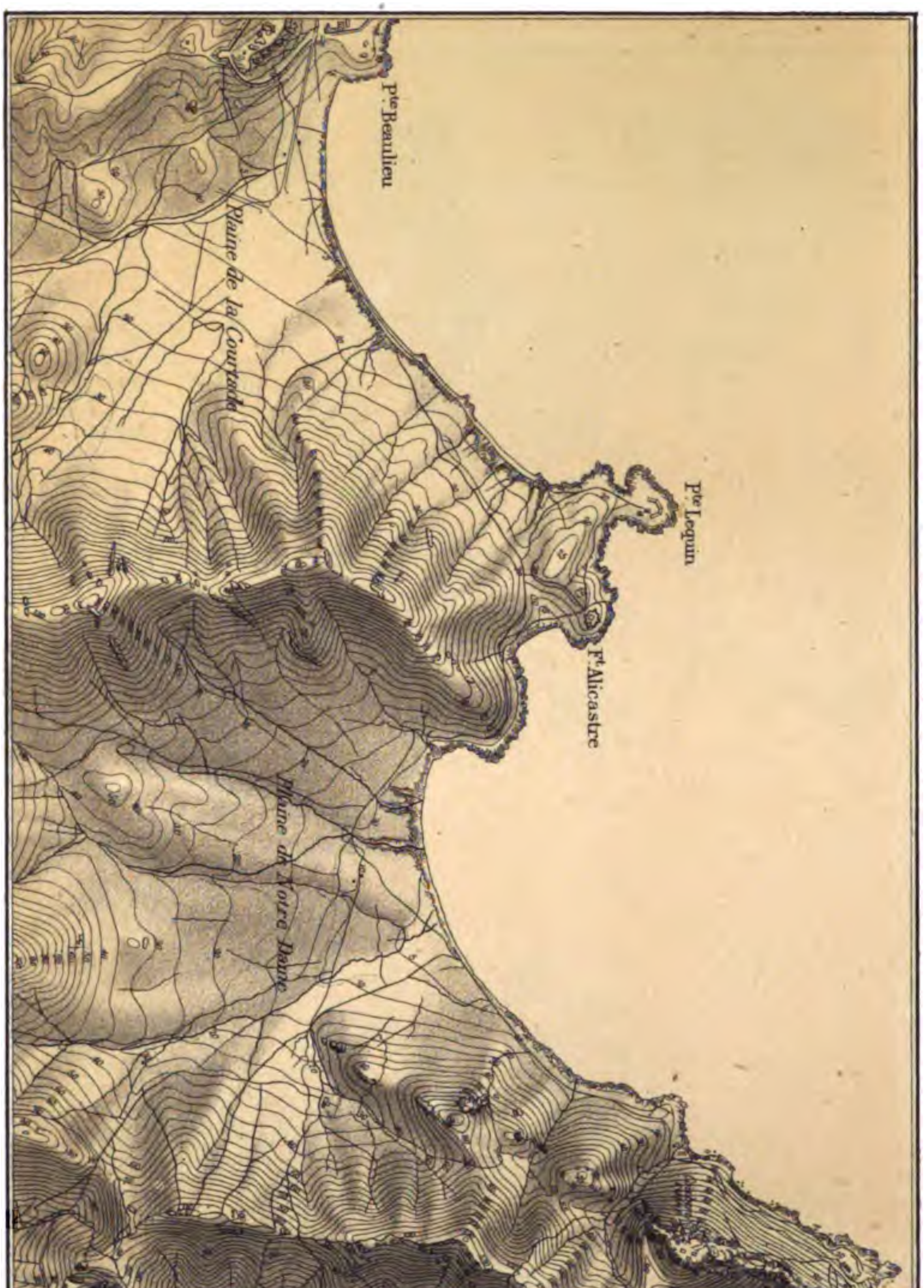


SCALE $\frac{1}{20,000}$

Vincent Brooks

London Published June 1864 by Atchley & Co 106, Gt Russell St. W.C.

FROM PROFESSOR BARDIN'S SERIES.



SCALE $\frac{1}{20,000}$

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London Published June 1864 by Ashley & Co 106 Gt Russell St W.C.

Vincent Brooks, lith London

London. Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

PLATE XXVII.

Vincent Brooks, lith. London

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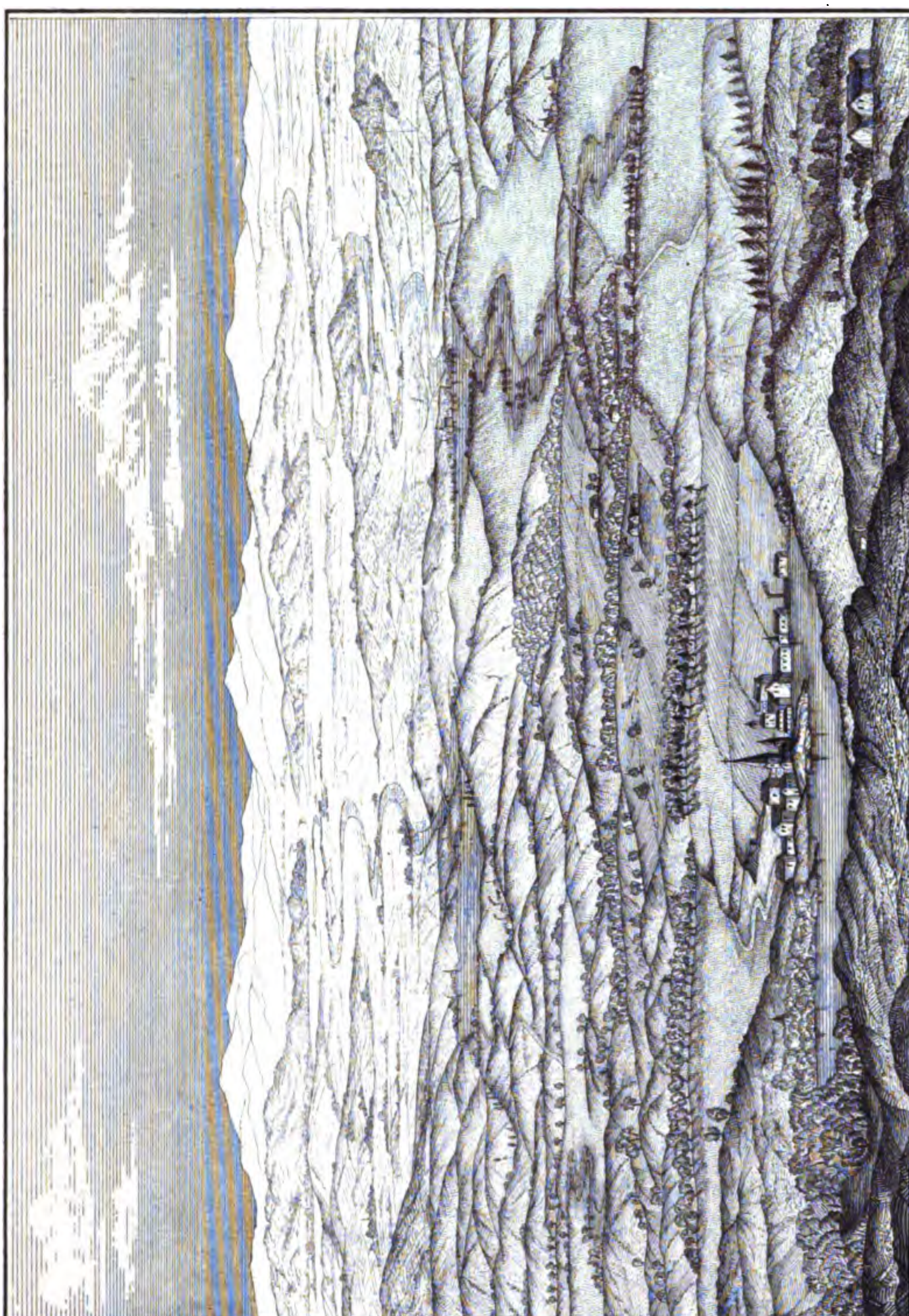
PLATE XXVII (a).



Vincent Brooks Lith London.

EYE SKETCH.

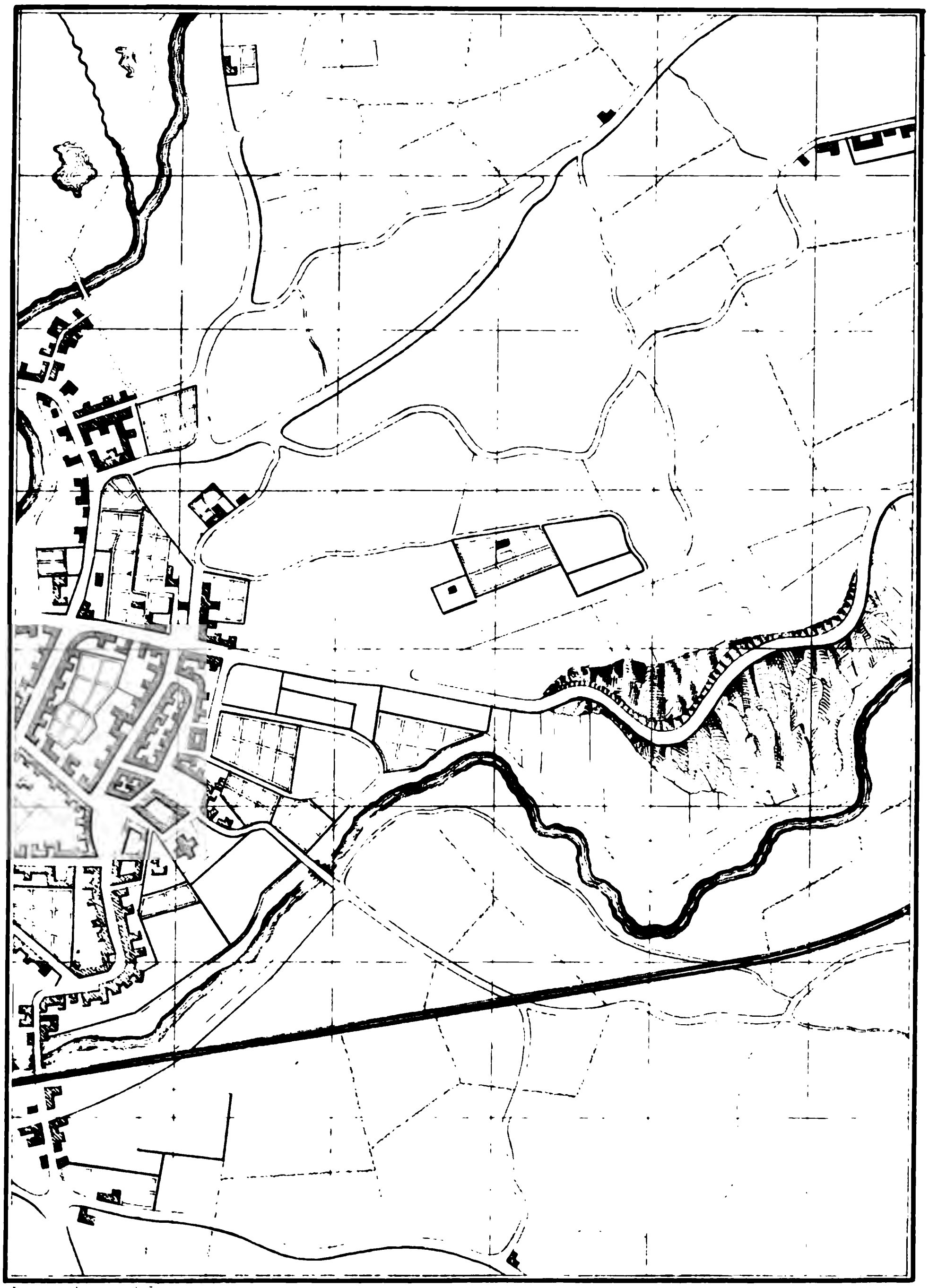
London Published June 1864 by Atchley & Co 106, Gt Russell St W.C.

FROM WYLD'S MAP OF THE WESTERN PYRENEES.

(ANALYTOGRAPH PROCESS)

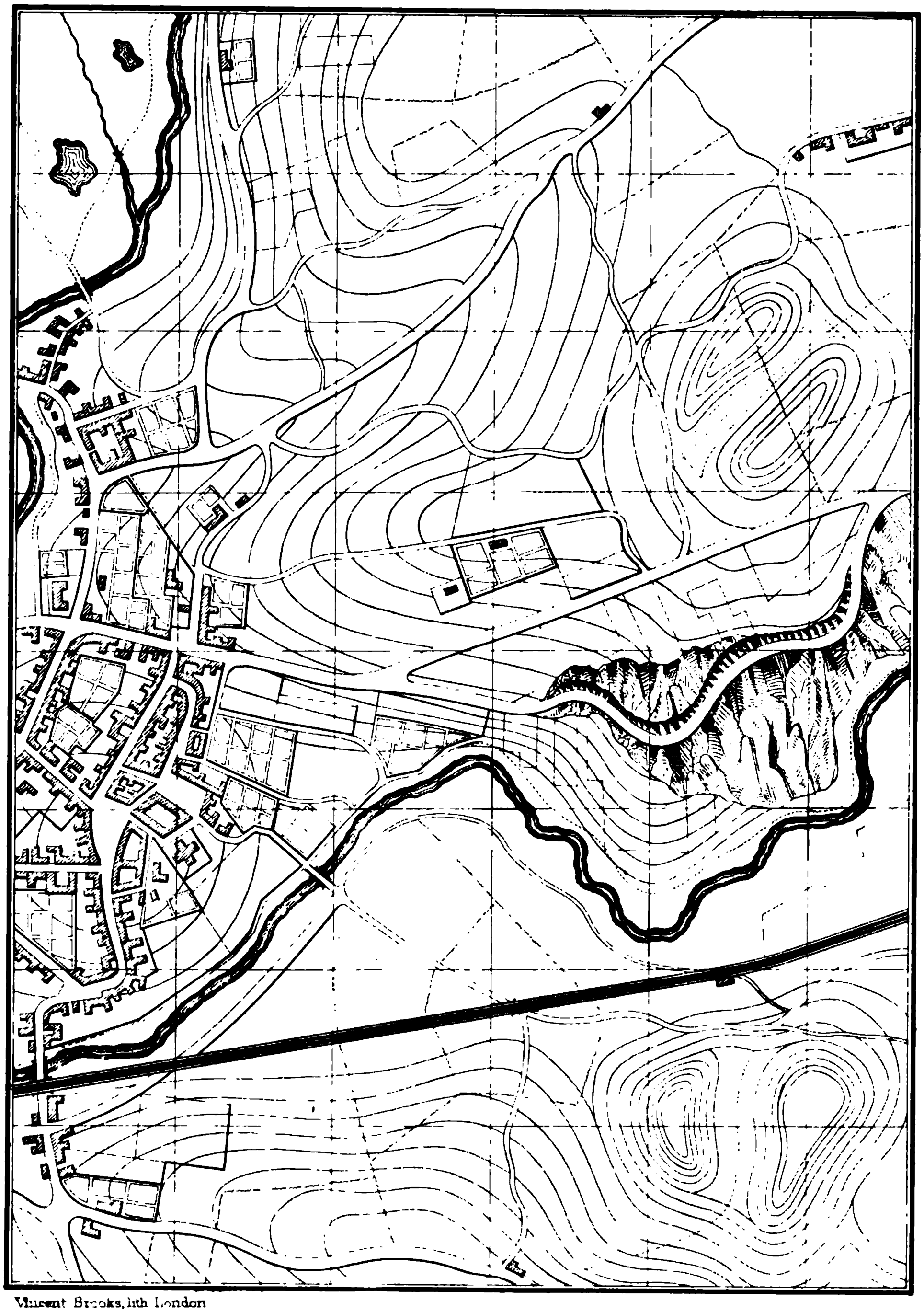
Vincent Brooks, Photo-litho London

London Published June 1864 by Atchley & Co 106 Gt Russell St W.C.



London Published June 1864 by Atchley & Co 106, Gt Russell St W C

PLATE XXIX



Vincent Brooks, lith London

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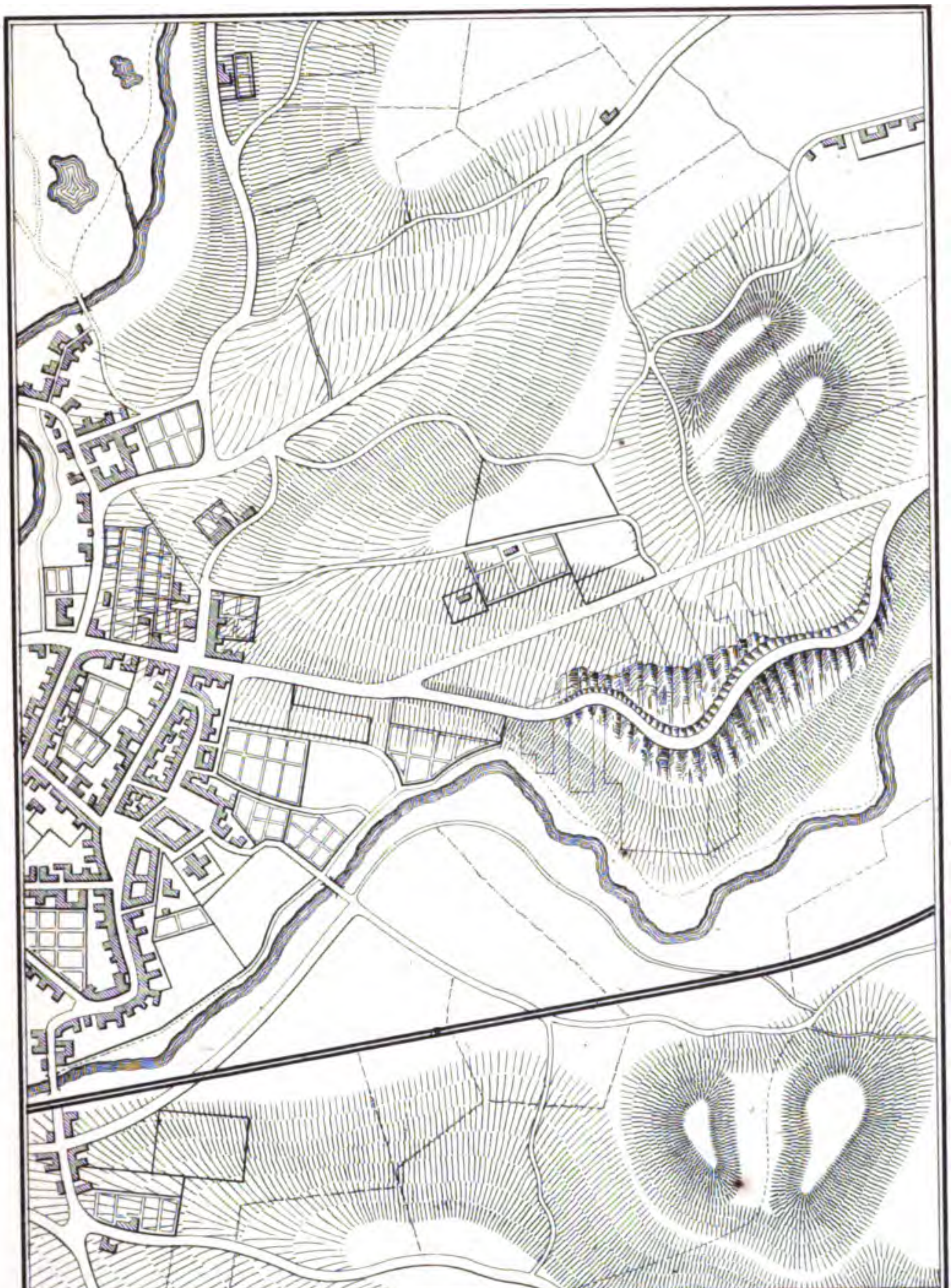

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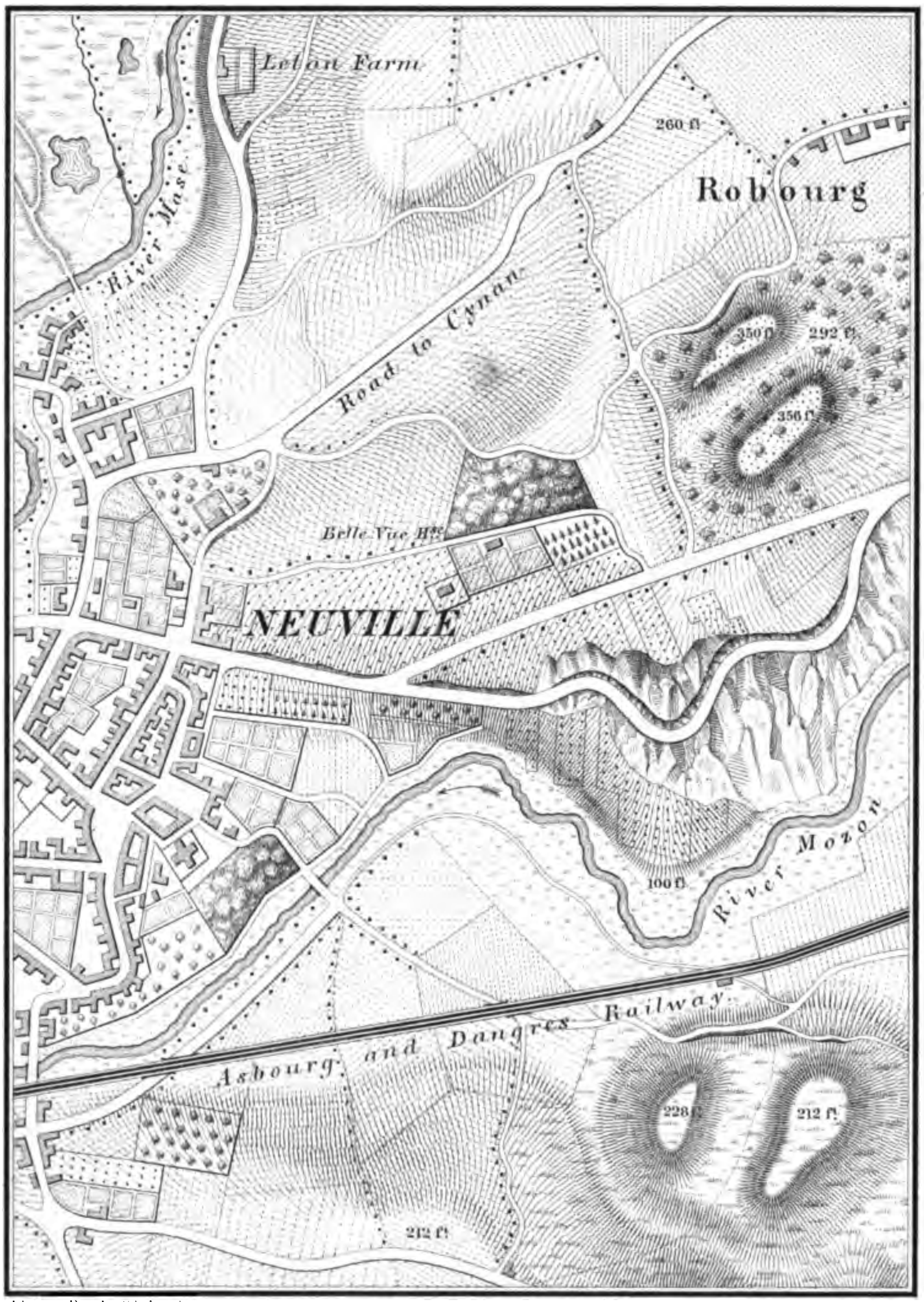

Scale of 6 inches to 1 mile.

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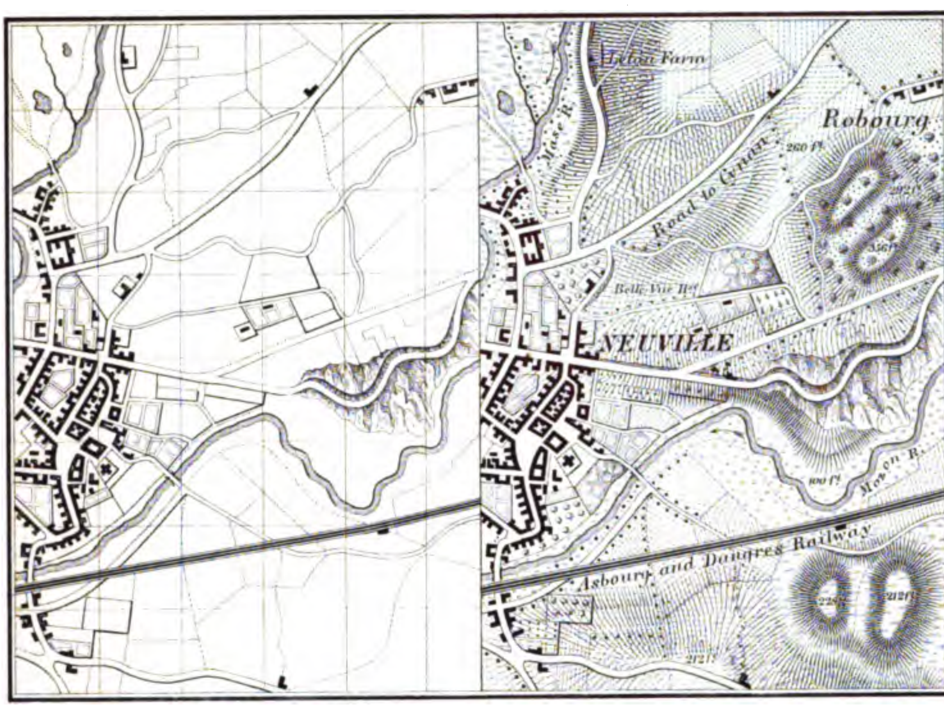

Scale of 3 inches to 1 mile.

Vincent Brooks, lith. London

Scale of 2 in. to 1 mile.

Scale of 1 in. to 1 m.

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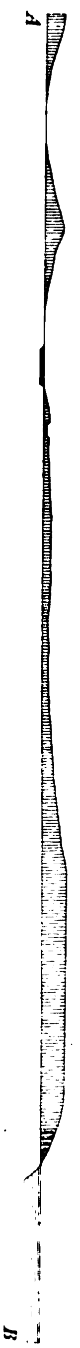
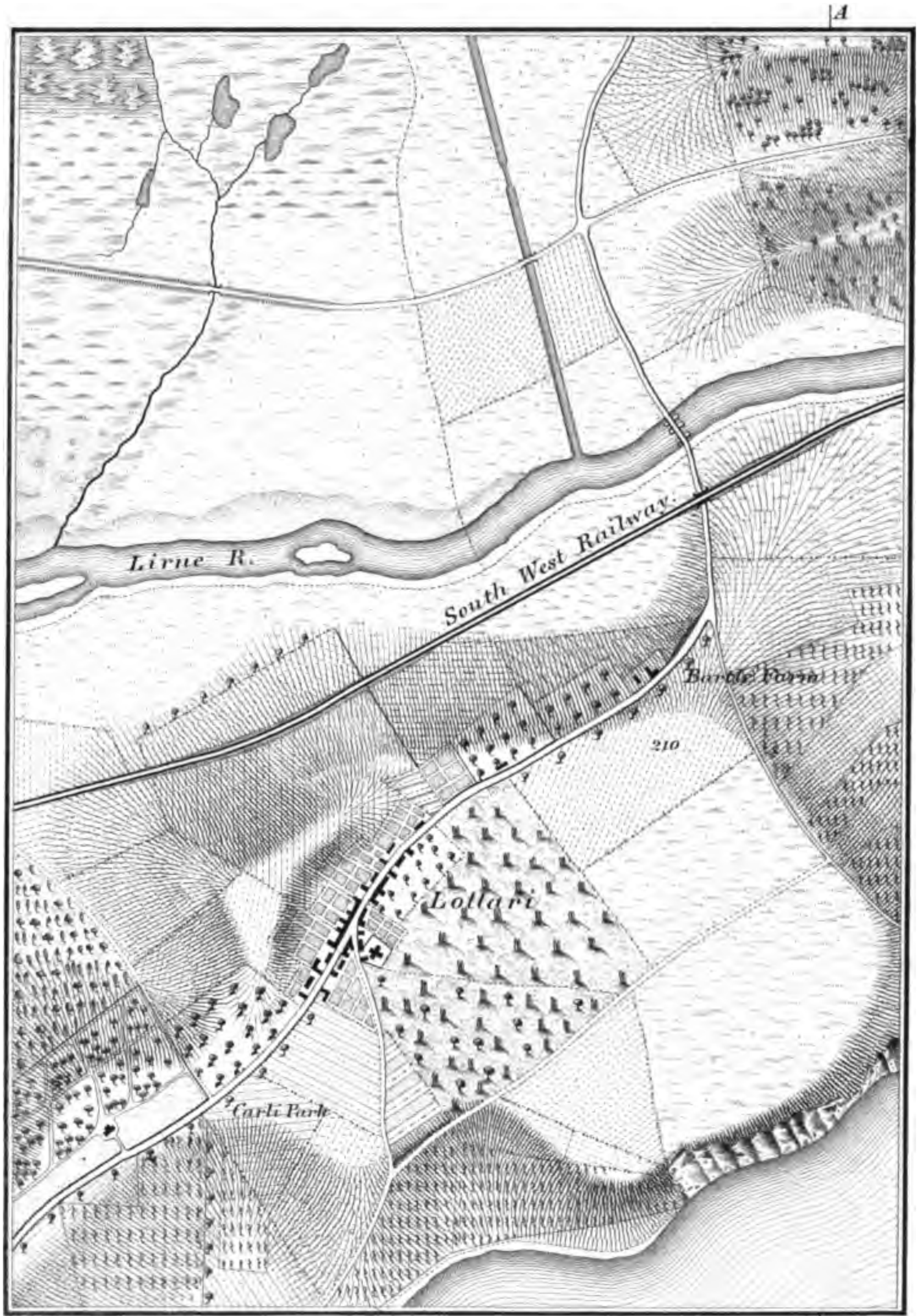


Section on A B.



Vincent Brooks, lith. London.

Scale of 3 inches to 1 mile.

London Published June 1884 by Atchley & Co 106 Gt Russell St W.C.

PHOTO-LITHO OF THE ENGLISH ORDNANCE SURVEY, (YORKSHIRE)

London Published June 1864 by Atchley & C° 106. G^t Russell S^t W.C.

PLATE XXXV.

PHOTO-LITHO OF THE

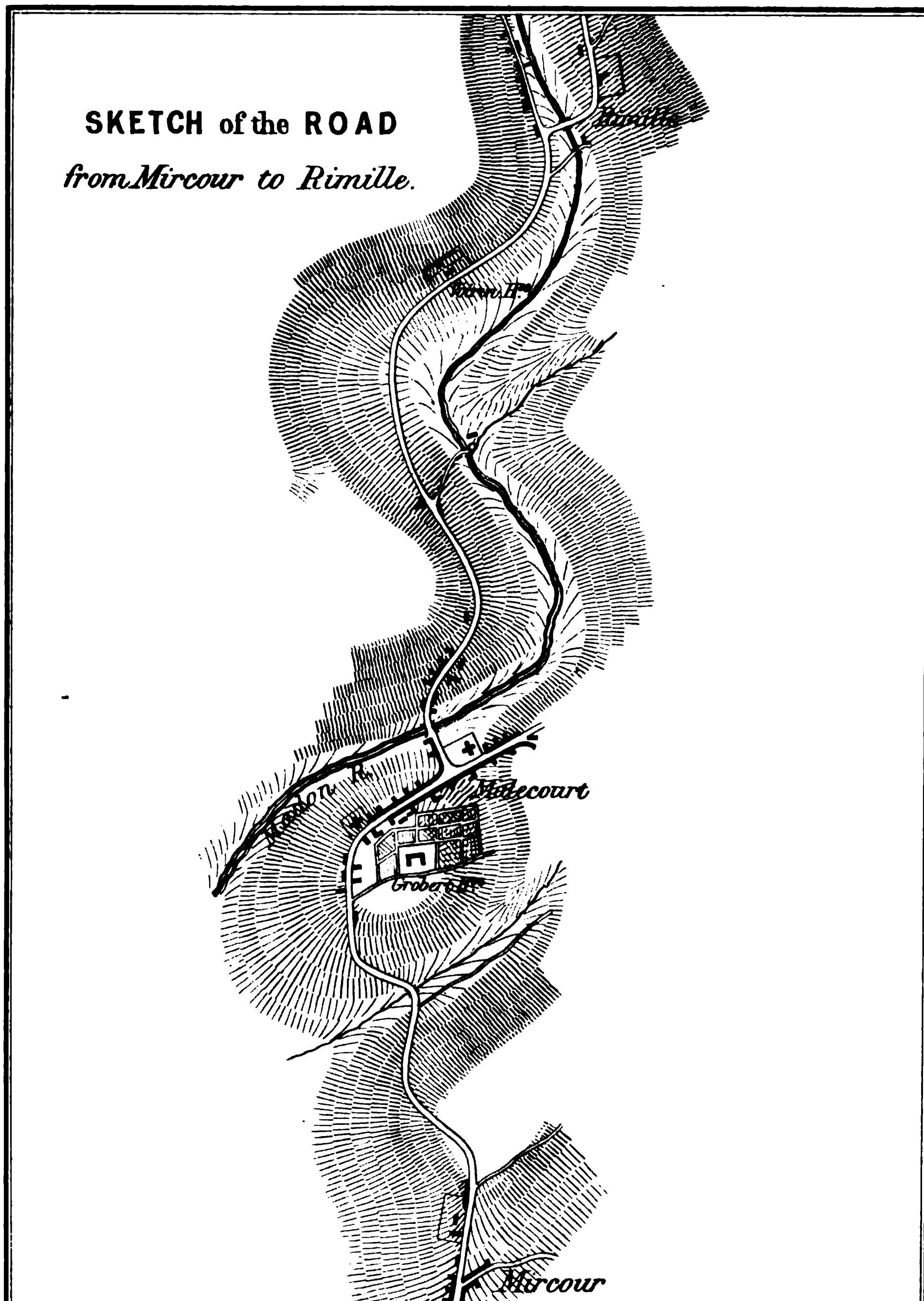
FRENCH ORDNANCE MAP,

(PYRENEES)

Vincent Brooks, Photo-litho. London.

SCALE $\frac{1}{80,000}$

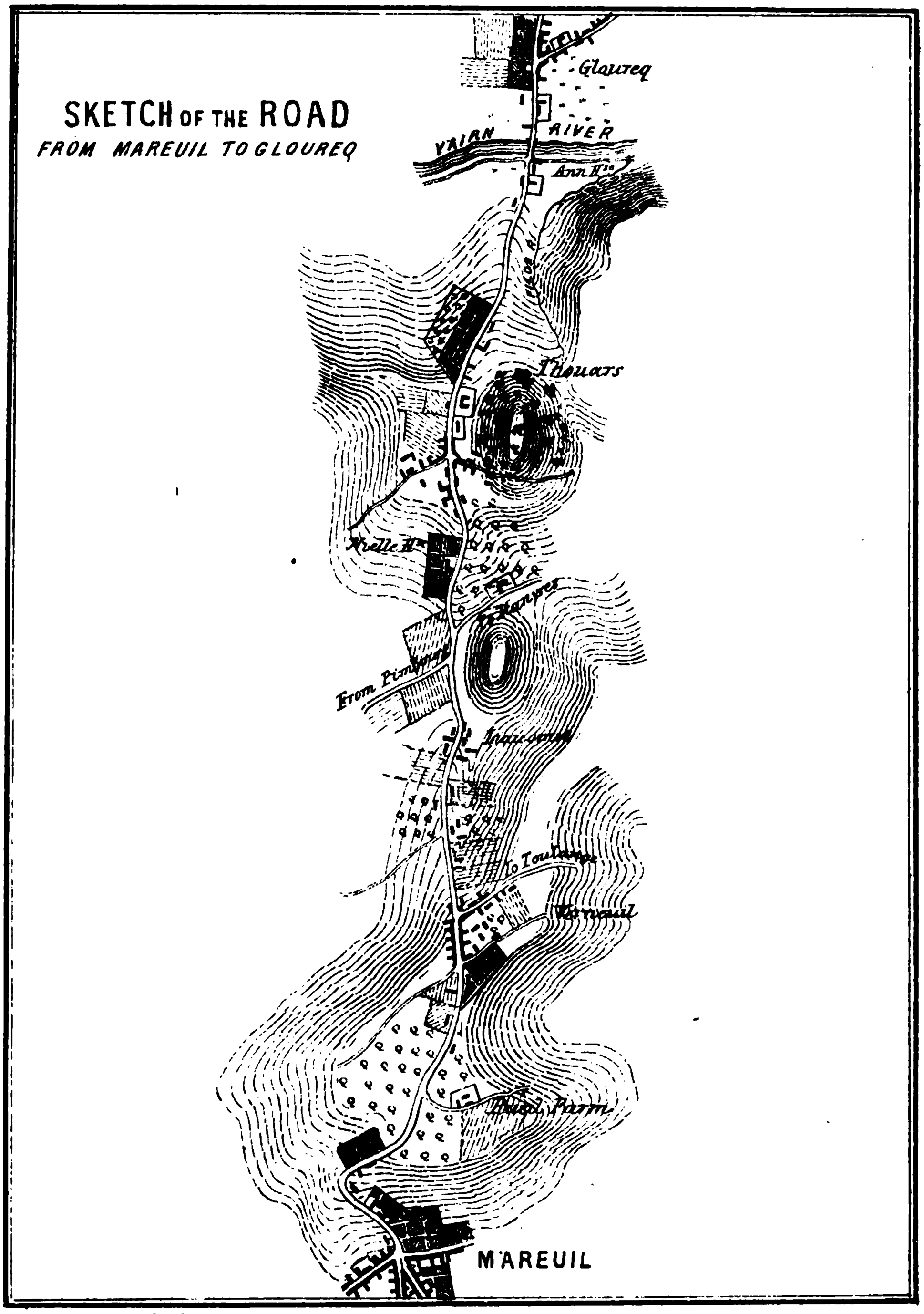
London: Published June 1864 by Atchley & Co 106. Gt Russell St W.C.



Vincent Brooks, lith London

SCALE OF 3 INCHES TO 1 MILE.

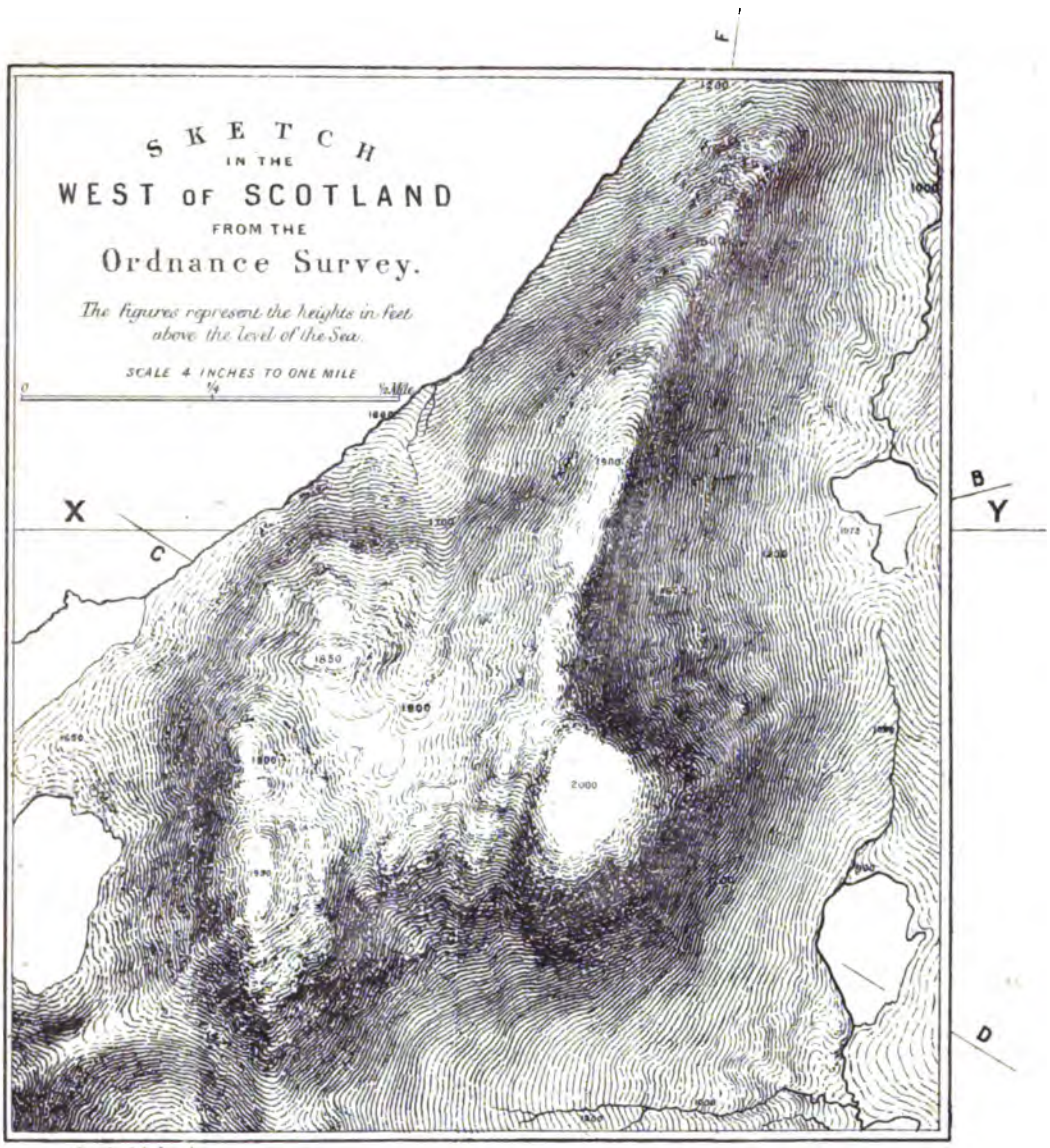
London Published June 1864 by Atchley & Co 106, Gt Russell St W C.



Vincent Brooks, lith. London.

SCALE OF 2 INCHES TO 1 MILE

London Published June 1864 by Atchley & Co 106 Gt Russell St W.C.



Vincent Brooks lith. London

Directions.

1. *Copy that portion of this example which is below the line* **X Y** *in pen or pencil employing either vertical or horizontal strokes to shew the form of the ground, or if you prefer it, use the brush for its representation.*
2. *Draw Sections on the lines* **A B, C D, & E F**, *as accurately as you can.*
3. *Print the Title in the characters used on the example.*
4. *Give specimens of the manner in which you would represent woods, marshes, rocks & villages on a plan drawn to a scale of* $\frac{1}{10800}$ *or 300 yards to 1 Inch.*

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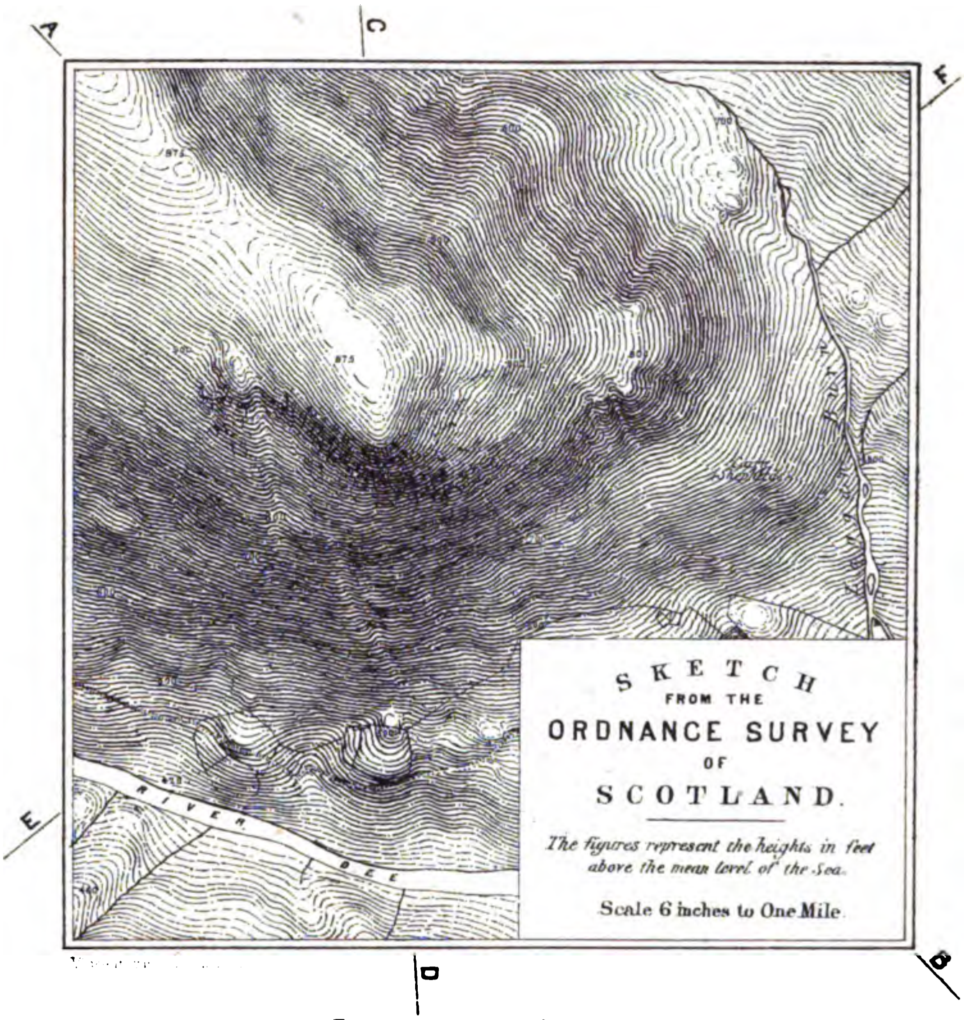
PLATE XXXIX.



Instructions.

1. *Copy the upper half of the plan in pen, pencil, or in brushwork; using a horizontal or vertical style of hâchure as you may prefer.*
   The dotted lines shew Contours at 20 feet vertical intervals and will be found useful in making the Sections. Their suppression in the copy will not be considered to detract from its merit.
2. *Draw a scale for the plan.*
3. *Draw Sections as accurately as you can on the lines* **A B, C D, E F.**
4. *Represent a marsh, a village, a sea beach & overhanging cliffs, & a wood, suitable for the above scale.*
5. *Print the Title neatly in the characters given in the copy*

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EXAMPLE O

ACCORDING TO COL(

(THE CHAIN-DOTTED

Vincent Brooks, lith London.

London Published June 1864

PLATE X

EXAMPLE OF HILL SHADING,

ACCORDING TO COLONEL SCOTT'S DIAPASON.

(CHAIN-DOTTED CONTOURS ARE NOT FIGURED)

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